104

THE X-33 REUSABLE LAUNCH VEHICLE: A NEW WAY OF DOING BUSINESS?

Y 4. SCI 2: 104/28

The X-33 Reusable Launch Vehicle: A...

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

OF THE

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

NOVEMBER 1, 1995

[No. 28]

Printed for the use of the Committee on Science

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THE X-33 REUSABLE LAUNCH VEHICLE: A NEW WAY OF DOING BUSINESS?

WEDNESDAY, NOVEMBER 1, 1995

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
Washington, DC.

The subcommittee met at 10:05 a.m. in Room 2318 of the Rayburn House Office Building, the Honorable F. James Sensenbrenner, chairman of the subcommittee, presiding.

Mr. SENSENBRENNER. Good morning.

Today the Subcommittee on Space and Aeronautics has convened a hearing on NASA's X-33 Reusable Launch Vehicle Program.

This program and its timely successful execution is fundamental to achieving the National Space Transportation Strategy issued by President Clinton last August.

If America can develop a fully reusable launch system with a simplified airline-like operation, the U.S. Government will not only enjoy the most economical access to space ever invented in the history of the space program, the industry team responsible for making that rocket will be able to capture international launch markets throughout the world which were lost by U.S. firms during the last ten years.

If we were operating in an ideal world, the NASA X-33 Program's limited budget of just over a billion dollars would leverage enough total investment by the X-33 Cooperative Agreement Teams to buy down the extraordinary technological risks associated with developing a radically cheaper launch system and leave private industry with only business risks to assume in developing an operational launch system that pays for itself, reduces the government's launch costs, and still makes money for its investors.

But of course everyone here knows this. This is Washington, D.C., and not the ideal world.

The purpose of this hearing is to judge the distance between the ideal program we all want and the program we have underway, a program which the House fully funded earlier this year.

To begin with, the program appears to suffer from an identity crisis of the first order.

On the one hand we are told X-33 is an advanced technology demonstrator like the X-1 or the X-15; on the other hand, we are told that this is an industry-led technology demonstration designed to commercialize a new launch system.

Which is it?

And what will it be?

Maybe it does not matter what terms are used to describe it, but it is important for all of us to look at the X-33 program and see the same thing.

To be sure, the X-33 is a radically different kind of business proposition for industry and a whole new way of doing business for NASA.

Traditionally industry has exerted tremendous effort to build a new launch system such as the ALS, the NLS, and Shuttle-C by lobbying for appropriated funds and working toe-to-toe with NASA and DoD to invent traffic for these government-owned and operated systems.

Here we have something entirely different.

We are trying to avoid the traditional NASA-pays-all procurement, at the same time expecting timely delivery of the X-33 demonstration vehicle on a fixed budget.

This could result in an X plane that tries to serve too many masters. It could result in an X plane that demonstrates more new technology and reduces more technology risks, or it could result in an X plane that competes with other forms of technology risk reduction that have potentially higher value to industry.

If technology risk reduction is NASA's primary contribution to industry, we must be sure that X-33 meets industry's needs.

So we will ask industry whether the current X-33 program provides them with ample incentive to invest their own money in the opportunity to develop the world's best new launch system, or if they need additional commitments by the government right now to make that happen.

If NASA is short-changing the industry on the front end, we cannot expect the industry to make investments now in X-33, nor to be there ready, willing, and able to build the operational system when America will need it.

If indeed the X-33 is a new way of doing business, NASA will become just one of many customers to use the operational launch system being developed by industry.

Industry is taking the business risk of developing the launcher and would be in a position to compensate its shareholders for their investment, but we cannot have it both ways.

We cannot have NASA assuming the business risk of this venture, for example, by signing a take-or-pay launch contract such as an anchor-tenant contract which would be like buying all our plane tickets to space at one time. At that point we might as well just own the airline.

Anchor-tenancy is a term that was borrowed from shopping center developers who try to get a large department store as an anchor tenant, thus attracting more traffic at higher rents for their development.

If an industry wants the government to be its anchor tenant in this system, it should come prepared to offer the public steep discounts in launch costs the way shopping centers give their anchor tenants reduced rents.

At the same time, the subcommittee is open to discuss other creative ways it can use the government's purchasing power for launch to help bring the next generation fully reusable launch system to market.

Finally, I hope we get to the bottom of another issue here today.

Earlier in this budget cycle the Senate Appropriations Committee included $20 million more than was requested by NASA for the X-33 program.

Meanwhile, our subcommittee and the Full Science Committee fully funded the President's request. I do not discount the possibility that this plus-up may be desired by some in industry who requested it, but it has made me very, very concerned that the program may already be experiencing cost overruns or, worse, that industry has not caught on with the spirit of the cooperative agreements.

The cooperative agreement notice issued by NASA on January 12th, 1995, told everyone how much government money would be available and when. NASA is living up to its word, and Congress is paying the bills.

It has been understood from the beginning that if industry wants to increase spending on the X-33 in one year or the other, they are more than welcome under the Cooperative Agreements to invest their own funds.

On the other hand, if there is a significant misunderstanding with respect to the Cooperative Agreements, clearly we should know about it today.

At this time, I would like to yield to the gentleman from Texas, Mister—the gentleman from California, Mr. Brown, for a statement on the Democratic side.

Mr. BROWN. Thank you very much, Mr. Chairman.

Again I wish to commend you for holding this hearing. The need for lower cost access to space has long been a concern of mine, and I believe that the Nation must make the investment in research and development that will enable us to move to the next generation of space transportation.

As you know, the issue underlying this hearing is not a new one. Looking back at the committee's Fiscal Year 1972 NASA Authorization Report, I was struck by the expectations for the Space Shuttle before it was built.

I quote from that report:

"The key to economical space operations in the forthcoming decades of space exploration is the space shuttle, a reusable space transportation system. It can revolutionize present-day space operations by providing airline-type accessibility to space at low operational costs. The shuttle will be designed for 100 or more flights with a minimum of ground maintenance. Payload transportation will be similar to commercial airline practice." End of the quote.

I think you would agree that, although the Shuttle remains a technological marvel and it represents a significant advance over previous systems, it never realized all of the operational and economic goals envisioned for it.

Then of course we can also recall the history of the National Aerospace Plane, NASP, which went through a similar touting as a potentially revolutionary advance; and then, like the Reusable Launch Vehicle Program, the NASP Program ultimately—let me restate that.

Like the National Aerospace Plane, which many of us saw as a potentially revolutionary advance in space transportation, like the

Reusable Launch Vehicle Program the NASP started with ambitious goals, a technology development program that was seen as very challenging but ultimately doable, and a confident government-industry team.

However, for a variety of reasons there is no NASP program today.

I ask unanimous consent to revise and extend the remainder of my remarks.

Mr. SENSENBRENNER. Without objection.

Mr. BROWN. But let me point out that, since the beginning of the space program the development of an adequate space transportation system, beginning with SATURN V, has been a major challenge which we have not distinguished ourselves for solving in a proper way.

I am very grateful that Chairman Sensenbrenner is approaching this in his usual systematic way with a careful attention to detail, and I am hopeful that under his leadership in this subcommittee we will be able to successfully achieve the next step in our development of a space transportation system.

And thank you, Mr. Hall, for being late and allowing me to get in a little statement.

[The prepared statement of Mr. Brown follows:]

PREPARED STATEMENT OF HON. GEORGE E. BROWN, JR.

Good morning. I wish to commend Chairman Sensenbrenner for holding this hearing. The need for lower cost access to space has long been a concern of mine, and I believe that the Nation must make the investment in research and development that will enable us to move to the next generation of space transportation.

As you know, the issue underlying this hearing is not a new one. Looking back at this Committee's FY 1972 NASA Authorization report, I was struck by the expectations for the Space Shuttle before it was built:

> "The key to economical space operations in the forthcoming decades of space exploration is the Space Shuttle, a reusable space transportation system. It can revolutionize present day space operations by providing an airline-type accessibility to space at low operational costs...The Shuttle will be designed for 100 or more flights with a minimum of ground maintenance. Payload transportation will be similar to commercial airline practice..."

I think you would agree that although the Shuttle remains a technological marvel that represented a significant advance over previous systems, it never realized all of the operational and economic goals envisioned for it.

Let me mention one other project—the National Aerospace (NASP), which many of us saw as a potentially revolutionary advance in space transportation. Like the Reusable Launch Vehicle program, the NASP program also started with ambitious goals, a technology development program that was seen as very challenging but ultimately doable, and a confident government-industry team. However, for a variety of reasons, there is no NASP program today.

The intent of these comparisons is not to disparage the goals of the Reusable Launch Vehicle program. Rather, it is to gently remind us that the establishment of a program to dramatically lower the cost of space transportation does not necessarily guarantee the success of that program. In part, this is because research and development by its very nature is not entirely predictable in its outcome.

Thus, I think that it is very important that as we aggressively pursue these advanced technologies, we not fall into the trap of creating a program that is so "success-oriented" that we are left with no good options if our initial technological and programmatic approaches are not successful. I believe that is the message of the NASA Advisory Council's recent letter to Administrator Goldin on the RLV program, and I think we would be wise to heed their counsel.

In closing, while I want to make sure that the RLV program is carried out efficiently and sensibly in the coming months and years, I think that NASA is to be commended for undertaking this cooperative, government-industry partnership to

develop advanced space transportation technology for the benefit of the U.S. launch vehicle industry. I am being only partially mischievous when I point out that this new program represents the same philosophy of public-private sector partnership that has guided the NASA aeronautics program—a philosophy that has been criticized by some as promoting "corporate welfare." I hope that the obvious merits of the RLV program will lead those who support this program while simultaneously questioning the appropriateness of the government's role in aeronautical R&D to reconsider their position.

Mr. HALL. Mr. Chairman, thank you for recognizing me. I would ask unanimous consent to put my opening statement in the record.

Mr. SENSENBRENNER. Without objection.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF HON. RALPH M. HALL

Good morning. I believe that today's hearing will be a useful opportunity to hear about a NASA initiative that may become increasingly important over the coming years, but which is now in its infancy: NASA's Reusable Launch Vehicle (RLV) program, and the X-33 project in particular.

As I understand it, the RLV program is a research and development program that is intended to demonstrate technologies that could dramatically reduce the cost of launching payloads into space. Lowering the cost of space transportation is a goal that I think all Members would endorse. I am a strong supporter of America's space program, but I want that space program to be carried out as cost-effectively as possible. Achieving low-cost space transportation is central to realizing economies in our space activities.

However, setting a goal of low cost access to space is one thing—achieving it is another. Unfortunately, we can all remember some failed attempts at developing new space launch systems that were to achieve dramatic cost reductions. We want to make sure that the RLV program is carried out in a manner that maximizes its chances of success.

Thus, as we embark on the RLV program, we need to better understand its objectives and the assumptions underlying the program. We need to know how much cost-sharing we can expect from industry, and whether a continuing financial commitment by the government is assumed for the development of the full-scale operational RLV. Finally, we need to know how NASA's need for a crew-carrying follow-on to the Space Shuttle will be met.

While there are many questions to be addressed, I think that we have an excellent group of witnesses that can help us sort through these issues. I look forward to their testimony. Thank you.

Mr. SENSENBRENNER. Without objection, other Members may put opening statements in the record at this point.

Mr. SENSENBRENNER. Also without objection I would like to insert into the record a statement prepared by Lori Garver, Executive Director of the National Space Society, into the record at this point.

Mr. SENSENBRENNER. Are there any objections on any of these unanimous consent requests?

[No response.]

Mr. SENSENBRENNER. Hearing none, so ordered.

[The prepared statements of Mr. Cramer and Ms. Garver follow:]

Prepared Statement of Hon. Bud Cramer

I want to express my support for the Reusable Launch Vehicle (RLV) program. It is crucial to the United States to reduce the cost of space transportation. That objective is key to our future civil space exploration and commercialization programs.

NASA's RLV program is designed to tackle that challenge, and it promises to do so in ways that will revolutionize not only our technology, but the nature of government-business relationship as well.

I am proud of Huntsville's role in the X-33 program. Marshall Space Flight Center has long been the leader in development of launch vehicles—from the first launch of man into space, to the Saturn V which took men to the moon, to the space shuttle.

In the X-33 program, Marshall continues to provide that launch vehicle expertise with its employees working side by side with industry to help make a resuable launch vehicle possible.

NATIONAL
SPACE SOCIETY

Statement Prepared for a Hearing of the

Space and Aeronautics Subcommittee

of the

House of Representatives Committee on Science

on

NASA's Reusable Launch Vehicle Program

by

Lori Garver

Executive Director of the National Space Society

November 1, 1995

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Mr. Chairman and members of the Subcommittee. On behalf of the National Space Society (NSS) I want to thank you for arranging this hearing to examine NASA's Reusable Launch Vehicle (RLV) program and for allowing the NSS to submit this statement for the record.

In the view of the National Space Society, which represents tens of thousands of members nationwide, the RLV program is the most critically important initiative now underway at NASA to advance the future development of the space frontier.

There are compelling reasons for America to now invest with industry in building a completely reusable launch vehicle. An RLV will create new opportunities for exploration and scientific research, as well as open the door to the large scale commercialization of space. Investing now in a next-generation RLV holds the promise of substantially reducing the future costs of traveling to and from the International Space Station. The new RLV will make going to space much safer for humans because the vehicle does not rely on solid rocket boosters that are inherently dangerous. And importantly, the new RLV will provide America a competitive edge so our aerospace industry can recapture lost ground in the global market for commercial space payloads.

Humans long have dreamed about conquering the heavens and exploring the vast universe. Unfortunately, our imaginations have far outstripped the technological realities. A formidable barrier still exists to accessing space in a launch vehicle that is affordable, reliable, and efficient to operate.

NASA understood this important goal when it first set out to build a reusable launch vehicle more than 25 years ago. Neil Armstrong had just set foot on the Moon and the space agency was looking to take the next giant leap into the future. In 1972, with the Apollo era coming to a close, Congress approved funding to begin building the Space Shuttle. Advocates predicted the new launch vehicle would considerably lower the cost of traveling to space and make obsolete America's expendable launchers.

Unfortunately, the shuttle program failed to live up to expectations. Engineers, in retrospect, blame the vehicle's design and technological problems. The Space Shuttle was built to carry heavy payloads to and from space. It cannot fly remotely and must always have humans aboard to help pilot the craft -- an expensive and technologically complex requirement. The vehicle also functions as a scientific laboratory, remaining in orbit for a couple weeks at a time. In a sense, the Space Shuttle is a "Swiss Army knife" approach to designing a launch vehicle -- it does a little bit of everything, but excels in nothing. The Space Shuttle gets the job done, but the process is overly complex and inefficient. To maintain the orbiter between flights requires an army of technicians. Each mission alone costs nearly $500 million.

Despite the Space Shuttle's shortcomings, the program has served a valuable purpose and will continue to do so in the years ahead. The shuttle will be used to launch the components of the International Space Station, carry spacecraft into orbit for launch to other planets, conduct scientific missions, and service the Hubble Space Telescope. Although the shuttle is only partially reusable, its design importantly propelled technology forward and moved the development of spacecraft beyond expendable launchers.

Now NASA is laying the groundwork so industry can afford to build a fully reusable launch vehicle that is economical to operate and easy to maintain. The new RLV, as currently conceived, will be highly automated and used primarily to launch commercial and governmental satellites. It also will have the capability to ferry humans to and from the International Space Station.

NASA's approach to building the new RLV is a radical departure from the past when engineers embarked on the Space Shuttle program. At that time, engineers moved directly from the drawing board to building a full-scale orbiter. Nine years after its authorization by Congress, the shuttle completed its maiden flight. The vehicle was plagued by many problems and it wasn't until after the fourth mission that the shuttle finally was declared "operational" in 1983.

NASA and industry learned a great deal from building the shuttle, including what not to do in future projects. Today's RLV initiative does not seek to design and build the next-generation vehicle in a single leap. Instead, it is fashioned after NASA's highly successful aeronautical research program in which engineers build a little, then test a little, learning step by step how to overcome technological problems and make improvements to designs.

Importantly, NASA is not shouldering the entire cost of developing the new RLV as it did with the Space Shuttle. Times have changed and so has NASA. The new RLV program is a partnership between industry and NASA. Together, they are sharing the cost of developing the advanced technology needed to build a completely reusable launch vehicle.

The RLV program is divided into two parts, the X-33 project and the X-34 project.

The X-33 project includes both the initial design work and development of the advanced technology needed to successfully construct a single-stage-to-orbit vehicle. Industry engineers now are working on various design concepts for the new RLV, one of which will be selected for development in the summer of 1996. During the second phase, NASA and industry will jointly construct a half-scale model of the RLV for test purposes. When this work is completed, NASA and industry hope the risks will have been sufficiently reduced such that industry can afford to finance, build, and operate a full-scale RLV.

In addition to the design work, as part of the X-33 program, engineers from NASA and industry are working to overcome the technological difficulties associated with building a completely reusable vehicle. There are four major areas of research activity.

First, to successfully operate as a single-stage-to-orbit spacecraft, the structural weight of the RLV must be reduced to about 10 percent of the overall vehicle's weight when fully fueled. To achieve this goal, engineers are building and testing structural components made from lightweight, composite materials.

The RLV rocket engines will burn hydrogen and oxygen, the same as the shuttle's liquid-fueled engines. The fuel is stored in separate tanks that must be cooled to -423 degrees Fahrenheit for hydrogen and -298 degrees Fahrenheit for oxygen -- the temperatures at which the gases become liquefied. Upon reentry the RLV will experience intense heat. So, as a second area of research, engineers are designing lightweight fuel tanks that are structurally very strong and able to repeatedly withstand the extreme temperature variations.

The third area of investigation involves building a thermal protection system that is lightweight, easy to maintain, and waterproof. The thermal tiles used on the Space Shuttle require nearly 20,000 man-hours between flights to make repairs.

The fourth area of research focuses on improving engine reliability. To propel the Space Shuttle to orbit (because of its weight) requires that its liquid-fueled engines operate at over 100 percent, which causes extreme wear and tear. As a consequence, after each flight, the engines must be completely rebuilt an expensive and time consuming process. The same engines, however, can be used repeatedly if they are not pushed to the maximum limits. For the new reusable launch vehicle, engineers are planning to operate engines at lower RPMs and thus eliminate the requirement to rebuild them after every mission. Engineers are upgrading existing rocket designs to improve performance and extend their operational life.

In addition to the X-33 project, NASA and industry are building a small, multi-stage vehicle, dubbed the X-34, for use as a testbed to validate the technologies needed to build the RLV. Flight testing of the X-34 is scheduled to begin in late 1997. The vehicle will be launched from the top of a 747 jetliner. Rockets will ignite and the X-34 will fly to space by remote control, then return to Earth, landing on a runway. While in space, the vehicle will have the capability to deploy an upper-stage rocket attached to a lightweight payload. The X-34 will be used by NASA and industry to test structures made of composite

materials, thermal protection systems, reusable fuel tanks, hypersonic airbreathing engine designs, health monitoring systems, and advanced avionics for automated flight. Eventually, a privately built vehicle based on the X-34 design will be used to deliver small (Pegasus class) commercial payloads into space.

The purpose of this subcommittee hearing is to look at the viability of NASA's strategy to reduce risk sufficiently so industry will be willing to finance and build a full-scale RLV early in the next century.

Obviously, NSS cannot speak on behalf of the aerospace companies that directly are involved in the RLV program. Personally, I do not think it is possible to allay all doubts about the program's future success. Still, the National Space Society believes NASA's strategy to enable private industry to build the new vehicle is well conceived and deserves the strong support of members of Congress. NASA's build-a-little, test-a-little approach to designing the new RLV ensures that the program does not overpromise what can be delivered. The advanced technologies that must be developed will be proven before work begins on a full-scale RLV.

The Shuttle was a grand attempt to build a spacecraft that can do everything. The new RLV is smarter, safer and simpler. It is being designed specifically to optimize efficiency and to keep operational costs to a minimum. Legions of people will not be required to fly and service the new vehicle. The X-33, X-34 projects are private industry's approach to making space travel truly affordable.

Looking down the road to the next century, the RLV can potentially save taxpayers billions of dollars. The International Space Station is expected to be completed in 2002. According to the General Accounting Office (GAO), over the following ten-year period, until 2012, NASA is expected to spend an estimated $45.7 billion to support the space station, of which $32.7 billion is pegged for the operation of the Space Shuttle. The new RLV's cost-per-flight by comparison is projected to be under $50 million, about one tenth the price tag of a current Space Shuttle mission. Thus, by investing now in the RLV, future expenses borne by NASA and American taxpayers can be dramatically reduced.

NASA, instead of paying the full ticket to operate the Space Shuttle, in the future would contract with industry as an anchor tenant for a certain number of RLV flights to the space station and back. The process is similar to what occurred 50 years ago when the government contracted with struggling private airlines to carry mail for the Postal Service. Having a guaranteed customer allowed industry the wherewithal to invest in the commercial development of the passenger plane. Over time, the airlines gained sufficient financial strength to stand on their own feet, and a new industry was born.

Congress now has the opportunity to repeat history by investing in the RLV program. Working in partnership with the aerospace industry, America can achieve the goal of building a fully reusable launch vehicle. The new RLV represents a major advance in space transportation. Dramatically reducing the cost of flying to space will open untold opportunities for commercial development, exploration, and scientific research. The RLV program will again make America the world's leader in launch technology, giving industry the ability to recapture lost markets and create new high-paying jobs.

The United States once dominated the world in launching commercial payloads. Now Europe controls more than 55 percent of the market and is steadily gaining ground. The RLV program is America's ticket to leap-frogging the competition and recapturing the lost markets.

Americans are proud of their space program and want to explore the space frontier. In the current environment of budgetary constraints, there is no more important investment Congress can make to help achieve the dreams of America and to reduce future costs in government spending. The National Space Society urges members of Congress to fully support NASA's RLV program and to make possible a new era in space travel.

- end -

Mr. SENSENBRENNER. Now to help us begin our dialogue, I am pleased that NASA has made Dr. Jack Mansfield and Col. Gary Payton available to us.

These gentlemen are responsible for the taxpayer side of the Cooperative Agreements, and I expect them to represent the taxpayers' interest as the major investor in the X-33 Program not only as NASA's program managers.

Joining them at the table today are three industry teams represented by Mr. Robert Minor of Rockwell International; Mr. Charles Ordahl of McDonnell Douglas; and Mr. Jack Gordon of Lockheed Martin.

We are also happy to have Dr. Ray Williamson, now a Senior Research Scientist at George Washington University Space Policy Institute.

Dr. Williamson oversaw the Office of Technology Assessment's Comprehensive Review of the President's National Space Transportation Policy, the policy under which the X-33 Program originated.

I wish to thank our witnesses for being here today and encourage them to summarize their written testimony which will be placed in the record in their entirety, without objection.

[No response.]

Hearing none, so ordered.

So, Dr. Mansfield, why don't you and Col. Payton lead off as you would like.

STATEMENT OF DR. JOHN E. MANSFIELD, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE ACCESS & TECHNOLOGY, NASA HEADQUARTERS; ACCOMPANIED BY COL. GARY PAYTON, DIRECTOR, ADVANCED SPACE TRANSPORTATION, NASA HEADQUARTERS

Dr. MANSFIELD. Thank you, Mr. Chairman.

I am very happy to be here, and I thank you for the invitation. I am sorry that Mr. Rohrabacher is not here.

I understand he has to be at a patent hearing. His continued interest in this has been a great help—

Mr. SENSENBRENNER. I am supposed to be there, too.

Dr. MANSFIELD. Oh, is that right?

[Laughter.]

Mr. SENSENBRENNER. That is the way life has been like this year in Congress.

Dr. MANSFIELD. The X-33 is really an important program for us. As you know, it has been 25 years since the U.S. has developed a new launch vehicle.

Since that time, the French have developed 5, and the Russians have developed 25 new rocket engines or more.

We are falling behind in access to space.

We are falling behind in our ability to be inventive and new in space. We are still flying vehicles of the '50s.

They are very good vehicles, but they are no basis for the Nation's future in space. They are too expensive.

The result of this is that only the highest value payloads and only a few astronauts are launched into space.

This is terrible.

All of the promise of space to lift our spirits and give us a new frontier for human endeavor is lost because we do not have the ability to launch anything but expensive payloads in space.

We really want to do something about that.

Because of the cost of launch, even our commercial launch satellites have fallen from 100 percent market share to about 30 percent.

The competition overseas is devastating because we have not done anything new for 25 years.

We think there is a way out.

That is why, in partnership with industry, we are trying to find the right thing to do, the right vehicle to build, how to build it, what to make it out of.

That is what the X-33 is intended to do. It is intended to give industry good, strong data points on what the technology is, what the components are, how they work, how well they work, data that we did not have when we built the shuttle.

It is going to generate an informed decision, a decision based on real operational data.

The X-33 is not a full-scale vehicle. It is not even an orbital vehicle. It is not a replacement for the shuttle. It is pure and simple an X plane.

It is a plane to find out whether the technology is as good as we think it is, and whether the vehicle can be operated within the costs we think it can be operated.

That is exactly what we need to know in order to build a full-scale RLV. That is what we did not have when we built the Shuttle program.

In order to be a success, the X-33 has to meet six criteria. Two of these are technical and four of them are operational.

The two technical ones are:

Can we build the structure as light as we think?

Can we build the engines as light as we think?

Are the mass fraction and thrust-to-weight ratio correct for a single-stage orbit?

We can answer that with the X-33 program.

The four programmatic ones are the ones that were not asked for the Shuttle Program and we have to ask them now.

Is this going to be totally reusable?

Is it going to be affordable?

Can it be operated like an airplane, several times a week?

And can it abort safely?

Can it come home safely and not be lost?

If we can demonstrate those four things, we have the basis of a commercially funded, commercially invested launch system that can carry us into the future.

Once the X-33 is finished, industry takes the lead. The government will continue to help as it can, but we will have done what we believe the government's job is right now, to define the limits of the possible—the limits of the possible technically, and operationally.

Now I want to mention something of the status of the program.

As you know, we are in full movement with our Cooperative Agreements. Last year when I came here I brought pieces of hardware.

This year I cannot do that because the hardware now is 8 feet wide and 12 feet tall. It is under test at McDonnell's subcontractor in Huntsville, Alabama. It is going to fly on the DCXA next spring.

There is a tank in Russia that is 8 feet wide and 12 feet tall. That is going to be delivered over here within a month or so.

We are building hardware. The rubber is meeting the road, and you are going to see a DC-XA flying next summer—next spring, and you are going to see a selection of an X-33 design next summer.

We are going to be on time with this. There is a 'Goldin Rule' at NASA—that is G-O-L-D-I-N—and that is. Do what you said you were going to do.

We say we are going to do this, and that is what we are going to deliver to you.

The program technically is in good shape, and I believe we are well on the way.

Our decision next summer will be based on a solicitation released next April. That solicitation will be discussed with industry well before that time, so that it will be well understood and will include all the elements that industry believe is necessary.

Once that is done, a selection team that we are now beginning to train will—once the solicitation is made and the proposal is received, this selection team will begin to work on this and we will have a selection for you by the end of June or early July that will be our selection of which X-33 design to go forward.

Now I recognize that—so I believe that programmatically and technically we are on the right track. Your questions of our financial health are serious and important ones. I realize that one of the major purposes is to determine whether or not we have the right funding at the right time, and whether we have to make adjustments to outyear funding.

With regard to the 1996 request, the budget for the RLV program for 1996 does the job. It is fully supportive of our program objectives for 1996. We do not need any more money for 1996 to attain the objectives that I just described.

Concerning the outyear funding requirements, there is not any single projection of what funding is going to be required. Given where we are right at the beginning of the program, what I can tell you is that the program that we presented to you, the funding we presented to you last year is a program with no reserve. There is risk in this program. There is risk that things might cost more, and things might take longer.

Normally you like to have a reserve in programs. Normally most programs do. This program has no reserve. So the budget that we presented to you, which was derived in 1994, is based on the best information there and is one that puts us to considerable risk. It is a risk we have to watch all the time.

Right now, I do not see any reason why the total amount of money is incorrect. The industry partners can comment on whether the money appears in the right years, and I believe that you would do well to ask them that.

We are reassessing these financial risks and the 1997 budget submission will address what we cannot of those, and we are going to work as closely with the committee as we can on that.

I think this approach is dramatically different, and I think it is the only one that can lead us to the promise of space through cheaper access to space. I thank you for your continued support in this area.

[The prepared statement of Dr. Mansfield follows:]

Statement of

Dr. John E. Mansfield
Associate Administrator
Space Access and Technology
National Aeronautics and Space Administration

before the

Subcommittee on Space and Aeronautics
Committee on Science
U.S. House of Representatives

Mr. Chairman and Members of the Committee:

I am pleased to be here today to discuss the status and progress of the Reusable Launch Vehicle (RLV) Technology Demonstration Program, focusing on the X-33 advanced technology demonstrator. I will begin by discussing our perception of the space transportation dilemma facing the Nation today, our approach to resolving this dilemma, our technical objectives, the progress that we have made to date, and our future plans.

In NASA's recent past, approximately one third of each annual budget has been spent in launching people, experiments, and spacecraft into space. DOD is also spending over one billion dollars per year for only a few launches. Launch costs are so exorbitant that only a small number of launches are possible today. Space access is consuming a disproportionate share of valuable resources (budget, talent, and facilities) and limiting our efforts to undertake the bold, aggressive, and exploratory endeavors that push our technology, imaginations, and spirits. Many valid space missions, experiments, and commercial endeavors go undone simply due to launch costs.

Additionally, other organizations and nations possess competitive advantages that have removed the U.S. from the preeminent position in worldwide commercial launch capability. The U.S. commercial space launch industry has dwindled from complete market dominance in the mid-1970's to less than 30% of the international market today. Launch costs also limit the growth of the U.S commercial satellite and telecommunications industries and prevent us from a true opening of the space frontier. This reduces the number of high-value American jobs, affects our international balance of trade, and stymies the emergence of a robust launch industry.

The Evolved Expendable Launch Vehicle and the consolidation of Space Shuttle operations are appropriate, near-term, interim measures to combat this cost problem. However, because the vehicles' configurations remain unchanged, these will only be stop-gap actions. The President's National Space Transportation Policy identified the need to balance these efforts on existing systems with the investment in improved future capabilities. With an aim farther in the future, the RLV technology program attacks the

fundamental problems of the U.S. launch industry through improved technology. The X-33 program consists of a ground test development and demonstration segment and a flight vehicle which will demonstrate these new technologies in a realistic operational environment.

Utilizing new technologies, the X-33 program aims at validating operational margins which will point the way to a more affordable generation of reusable launch systems. These developments hold the promise of driving down space access costs by an order of magnitude, attracting commercial interest in the ownership and operation of space launch systems, while expanding both commercial and exploratory activities in space. Government and industry are preparing to make decisions at the end of the decade on how to pursue more affordable access to space and will base our decisions largely on the results of this program.

A BETTER WAY OF DOING BUSINESS

The RLV technology program is unique to NASA in another manner as well. NASA is challenging the normal government to industry relationship and has made this program industry-led, with a goal of complete private sector financing and private operation of the next generation system. We have formed a partnership with industry and we are maintaining a streamlined management office with clear lines of authority and limited government oversight. The industry partners are using NASA resources and engineering staff at their discretion, with NASA laboratories acting as a "subcontractor" to the partnership. Government laboratories, at the request of industry, are fabricating advanced hardware, testing hardware, and participating in vehicle design and analyses. NASA engineers take instructions directly from industry leads, eliminating the bureaucracy associated with past NASA programs. NASA has a more coveted "insight" into the workings of the industry teams versus the typical "oversight" role of traditional Government. Both Government and industry participants are excited with the progress and results of this management arrangement so far. This is an example of how we are redefining the entire culture and challenging Government and industry to change our ways and drive down cost.

Moreover, industry is more than simply leading the RLV technology efforts -- they are truly stakeholders in the program. Along with increased responsibility, industry is contributing resources to the effort as a part of the partnership. During the first phase of the X-33, industry is contributing 50% of the total program dollars required. Industry does not make profit during the RLV technology program, in anticipation of the commercial potential of the next generation operational RLV. Government funding is fixed for the program as it is now scoped. This is a truly revolutionary way to manage technology development programs.

Industry is responding well to this new management arrangement. They have taken responsibility for defining the test vehicle configurations and basic technologies required to achieve the program goals. Their determinations are based on business projections not just performance needs. Together, we are defining the issues to be resolved, the obstacles to be overcome and the efforts to be undertaken over the next four years in

order to help make industry's business projections real and successful. Industry will provide the details of their plans, designs and approaches as part of their X-33 proposals next year.

A FOCUSED APPROACH TO TECHNOLOGY DEVELOPMENT AND DEMONSTRATION

NASA plans to use a focused development and ground and flight test program to demonstrate that the promising but technologically-challenging SSTO concept is feasible. The X-33 advanced technology demonstrator will be the culmination of these ground and flight test activities. The X-33 will integrate and flight test advanced components in the realistic combined environments of launch, landing, and ground handling. In concert with an extensive ground test program, the X-33's objective is to generate the technical and programmatic data necessary for making an informed decision by Government and industry on the feasibility of proceeding with an operational RLV. It is not, in itself, a full-scale, orbital vehicle or a replacement for the Shuttle.

Industry will take the lead in any future cooperative efforts to build an operational RLV. Critical technologies will have been developed in the X-33 program that should have direct applicability in upgrading the Space Shuttle and improving evolved expendable launch vehicles (EELVs).

The future of America's launch fleet will be based on the degree to which an affordable launch system can be fielded based on the key characteristics of reusability, affordability, operability and safe abort capability. I would like to discuss, briefly, each of these key characteristics, to provide you a better understanding of why we believe that the next generation system will provide the launch cost reductions needed to open the space frontier.

Reusability

Maximum reusability is crucial for any low-cost launch vehicle, because the fundamental characteristics of expendable and partially expendable systems drive up costs. The expended hardware must be manufactured for each, flight creating a need for extensive fabrication, assembly, and shipping infrastructures. Staged vehicles demand extensive facilities and work forces for the hoisting, aligning, mating, and verifying of each component as the vehicle goes through assembly before each flight. Moreover, since each vehicle is a newly assembled vehicle, flight certification for each component and each stage is necessary for each flight. This demands an additional infrastructure of test equipment and analyses to certify the vehicle before each flight.

Each of these demands in support of expendable hardware is manpower intensive, thus the dominant cost of current launch systems is labor. Thousands of individuals are involved in the manufacture, refurbishment, assembly, and launch preparations for each flight of any U.S. launcher. The upgraded DC-XA, the X-34, and the X-33 are to demonstrate that small work forces can prepare, launch, and recover a modern rocket-powered vehicle. These vehicles can be launched and serviced between flights by small

crews because a vehicle that reuses the same hardware used on the prior flight does not need a huge manufacturing and shipping infrastructure.

Affordability

Substantially lower costs combined with reliable flight performance is to key attracting launch business, commercial financing, and low insurance underwriting. Each reinforces the other.

To achieve the reductions that are required in launch costs, the next generation of launch capability must initially narrow its focus to efficient transportation to and from low Earth orbit. An operation styled after an airline or shipping company rather than a multimission research and development project is key. The system must be designed to meet its dominant transportation mission and must leave activities such as microgravity research, life sciences and astronomy to platforms such as the Space Station and science spacecraft which are specifically designed for these tasks.

Also, maximum cost savings would, theoretically, come with single-stage vehicles such as the X-33, which will have no requirements to mate stages, thus simplifying launch preparations. In a manner similar to operational aircraft, a fully reusable system refuels, undergoes routine maintenance between flights, and can be licensed as a fleet to overcome the expense of flight-by-flight certification. Without the need for continual manufacturing, stacking and recertifying a multitude of elements, the work force and dollar cost of a next generation single-stage launch system will shrink dramatically

Operability

Operability cannot simply be a goal for the next generation launch system; it must be a design driver. Every aspect of the program must improve operations. Technology investments must be focused on improved operations and simplicity. Today's launchers cannot be made substantially more operable, because the large number of tasks required to prepare current vehicles for launch greatly reduces operability.

In addition, current launchers are old designs operating at the edge of their performance envelope. Operating at the margins demands a large work force to gain as much reliability as possible. A vehicle operating substantially within its margins, and with reliability as a fundamental design objective, will require less maintenance between its routine flights. Mission manifests will be more predictable and achievable with no payload backlog accumulation due to failures or grounded fleets. This increased availability will mean more predictable launch dates for payload users, more accurate flight schedules, and -- bottom line -- greater revenue for a commercial operator.

The RLV program is focusing investments on technologies which should allow substantial improvements in operability and reliability by automating, simplifying or eliminating as many tasks as possible. Automated flight and landing avionics, improved, low-maintenance thermal protection systems and integrated vehicle health management systems offer the potential of dramatic reductions in inflight monitoring

and control from the ground, as well as in ground maintenance. The X-33 will demonstrate these operability and reliability improvements in the same launch, landing and maintenance environments to be experienced by an operational RLV.

Several aerospace systems, particularly the latest generation of military and commercial aircraft, offer legitimate examples of sophisticated systems being operated while maintaining small infrastructures. These advanced systems prove that, when designed for operability and operated within a well defined envelope, high-technology vehicles can be run efficiently and routinely. For launch vehicles, the DC-X has already demonstrated short vehicle turnaround with a 15-person work force. As a goal, the larger, more complex X-33 will demonstrate a turnaround of less than 7 days with a work force of 50 people or fewer.

Safe Abort

Unlike current, staged, expendable launchers, the next generation reusable vehicle will have inherent attributes to make it savable. The thermal protection system protecting it at the end of the mission will protect it during aborts. The vehicle health management system analyzing the vehicle for easy maintenance between flights will have the instrumentation for fault detection, fault isolation, and redundancy management.

This ability to recover offers many advantages: intact vehicles, intact payloads, surviving crews, and a more vigorous test program. This translates to improved reliability, which in a commercial operation, directly points to lower insurance costs. Today, commercial launch insurance premiums hover at 18%-20% of the insured value simply because the reliability of today's launchers demands such high premiums. Over the past several years, the spacecraft insertion success rate for commercial launchers has been only 86%, and lack of success for these vehicles usually means loss of the payload, as well as of the launch vehicle. Improved reliability and saved payloads, resulting from a savable vehicle, will lower insurance costs.

The operational RLV will be recoverable in all stages of its flight. The X-33 will demonstrate inherent abort capability as it incrementally expands its flight envelope during its test flights. Additionally, the requisite instrumentation and avionics necessary for fault recognition, fault isolation, and redundancy management will be demonstrated in both ground and flight tests.

RLV TECHNOLOGIES

As the foundation for demonstrating that a single-stage vehicle can be built with the necessary critical characteristics, the RLV program is advancing a broad selection of technologies, including: composite structures, composite tankage, insulation, robust thermal protection systems, vehicle health management systems, autonomous avionics, electromechanical actuators and operable propulsion systems. The DC-XA will be the first demonstration of composite load-carrying structures, insulated composite Liquid Hydrogen (LH2) tanks, a new alloy of Aluminum-Lithium (Al-Li) for its oxygen tank, and

an extensive instrumentation system with new sensors and data processing algorithms. This demonstrator will be followed by the X-34 which will fly many of the same technologies, but add robust thermal protection systems, a lined composite oxygen tank, and autonomous landing on a runway. Most importantly, the X-34, flying over a year before the X-33, will provide insight into the multiple reuse of these technologies before the final decision on the operational RLV. The X-33 will be the flight test vehicle to expose and prove all these technologies in the relevant combined environments of launch, landing, and preflight activities. Accompanying the X-33 flight test program will be a ground demonstration program to build experience in lifetime testing of components through hundreds of equivalent flight cycles.

As a test flight vehicle, the X-33 need not attain orbit, but it must experience all relevant environments except orbit (launch preparation, launch, hypersonic flight, landing and post-flight maintenance) in order to prove the promises of single-stage-to-orbit (SSTO) flight. While the X-33 will flight test robust thermal protection systems, composite structures, composite tanks, and advanced avionics, it will not be as large as the ensuing operational RLV, and most -- if not all -- of its engine components will be off-the-shelf. Therefore, it will not be capable of demonstrating the propellant mass fraction or engine thrust-to-weight required to reach orbit. Ground demonstrations of major structural subsystems and cryogenic tankage incorporating new materials, as well as engine component tests, are crucial to proving that a full-scale RLV will meet mass fraction and propulsion system requirements for SSTO.

The DC-XA, X-34, X-33, and the accompanying ground demonstration programs make up a series of incremental steps as we test new technology in increasingly demanding environments. Each contributes significantly to the complete set of information we need to prove the technologies for the next generation of U.S. launchers.

PROGRESS AND CURRENT STATUS

The RLV program is already making considerable progress. A series of cooperative agreements has been signed with industry to begin both ground demonstrations and flight vehicle design, development and testing. In cooperation with industry, ground-based technology efforts and the DC-XA flight demonstrator were initiated in 1994 to demonstrate lightweight structures, reusable cryogenic tankage, durable thermal protection systems, advanced avionics, and reliable propulsion components.

A cooperative agreement to design, manufacture and flight test the X-34 small-payload demonstrator was awarded to Orbital Sciences Corporation in March of this year. Initial flight testing is scheduled to begin in 1997 and suborbital flights in 1998.

Using a fast track procurement approach, cooperative agreements for X-33 Phase I (conceptual design) were awarded to Lockheed Martin, McDonnell Douglas/Boeing and Rockwell in March of this year. Proposal evaluation, selection,

negotiations and award of these three parallel 15-month efforts was accomplished in a matter of weeks, as compared to many months for similar size procurements using "business as usual" approaches.

These agreements are starting to show results. Since go-ahead for the ground technology efforts in the spring of 1994, this partnership has delivered the world's largest graphite composite liquid hydrogen flight tank, an all-composite intertank flight structure, and a composite flight feedline. The program has also tested a modular aerospike engine thruster (within 6 months from go-ahead), and demonstrated an expanded space shuttle main engine envelope.

The DC-X has been transferred to NASA from the USAF and is currently being upgraded to the DC-XA configuration with the incorporation of advanced technology components. It is scheduled for flight testing in the spring of 1996.

Each X-33 industry team is developing a business plan and operations plan for Phase II (design, fabrication and flight test), as well as doing X-33 preliminary design and technical trades. Each team, pursuing a design approach which is substantially different from that of the other two teams, has developed an SSTO vehicle concept to use as a basis for preliminary design of an X-33 that will flight test critical technologies for that design. Initial X-33 concepts have been developed by each team to use as a point of departure for the design cycles leading to completion of preliminary design in June of 1996.

FUTURE PLANS

Procurement plans for Phase II of the X-33 project are being finalized. The solicitation release is targeted for early April, with industry proposals due in late May. A fast track procurement approach, building on the successful process already demonstrated, is expected to result in a source selection by June. We plan to have a well-rounded source selection process, which will include expertise from the business and investment community, the launch services user community, and technical experts from NASA and other government agencies.

We expect all of the OMB/OSTP decision criteria for proceeding into Phase II to be fully satisfied. A final Non-Advocate Review (NAR) focused on the X-33 is planned in May 1996 with findings and recommendations from the NAR presented to the NASA Program Management Council in June. Certification by the Administrator is expected no later than the end of June 1996. These milestones are consistent with a Presidential decision for proceeding into development of the X-33 early next summer, leading to flight demonstrations to prove the concept of single-stage-to-orbit during 1999.

Mr. Chairman, I recognize that one of the major purposes of this hearing is to determine whether sufficient funding has been requested by NASA to achieve the necessary level of risk reduction, and whether adjustments to the outyear funding curve are required. Regarding the FY 1996 funding request, let me state that the budget the

President requested for the RLV program for FY 1996 is fully supportive of the program objectives and schedule I have been describing here today.

I would like to place the outyear funding requirements in some context. There is no single correct projection of funding required to achieve the goals of the RLV program. Instead, given where we are -- at the beginning of a cooperative, evolving technology development and demonstration effort -- there is a spectrum of risk for the RLV program which must be balanced against the risks across the agency as a whole. The FY 1996 runout budget for the RLV program was constructed in the summer of 1994 based on the best available information and a careful assessment of these RLV and agency risks.

Since that time, we have had considerable discussion with our industry partners, have had independent reviews of the program, have received recommendations from the NASA Advisory Council, and have undergone a Zero Base Review of the agency's institutions in response to major outyear budget reductions. As a result, NASA and the Administration are in the process of reassessing the balance of risks in the RLV program and in the agency as part of the FY 1997 budget process. Of course we will work as closely as we can with the Committee as soon as this process is completed.

CONCLUSION

The U.S. approach to space launch is undergoing a dramatic shift in its technology and management, with an equally dramatic drop in its future costs. The RLV program will deliver the technology improvements which lead to vehicles that capitalize on design characteristics of reusability, affordability, operability, and safe abort. Such robust vehicles, certified through a single test program, conducting well-defined transportation flights, and managed by a streamlined commercial work force, will deliver remarkable savings in space launch.

This is the path to leapfrog the competition and to open a new era in space access and exploration. This is not just a new vehicle; this is a new strategy that puts the U.S. back in its preeminent leadership role in space. This is a "Partnership for Space Launch Leadership," between government and industry. This is the future of American space launch.

Thank you, Mr. Chairman, for the support and cooperation of this Committee. We are ready to work with you in any way we can to advance this vital national effort.

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TOTAL RLV PROGRAM
FY 1996 PRESIDENT'S BUDGET

	1994	1995	1996	1997	1998	1999	Total
TOTAL RLV PROGRAM	**34.2**	**128.5**	**159.0**	**212.9**	**350.4**	**364.8**	**1249.8**
RLV SYSTEMS ENGINEERING & ANALYSIS	3.5	4.6	4.7	4.7	4.7	4.7	26.9
TOTAL RLV TECHNOLOGY PROGRAM	28.4	76.9	59.3	117.2	250.7	255.1	787.6
RLV FLIGHT DEMONSTRATION PROGRAM	2.3	47.0	95.0	91.0	95.0	105.0	435.3

TOTAL RLV PROGRAM
FY 1996 PRESIDENT'S BUDGET

	1994	1995	1996	1997	1998	1999	Total
TOTAL RLV PROGRAM	**34.2**	**128.5**	**159.0**	**212.9**	**350.4**	**364.8**	**1249.8**
DC-XA FLIGHT DEMONSTRATION PROGRAM	2.0	13.0	16.0	0.0	0.0	0.0	31.0
X-34 SMALL BOOSTER TECHNOLOGY PROGRAM	0.3	10.0	30.0	15.0	10.0	5.0	70.3
X-33 ADVANCED TECHNOLOGY DEMONSTRATOR	31.9	105.5	113.0	197.9	340.4	359.8	1148.5
RLV SYSTEMS ENGINEERING & ANALYSIS	3.5	4.6	4.7	4.7	4.7	4.7	26.9
RLV TECHNOLOGY PROGRAM	28.4	76.9	59.3	117.2	250.7	255.1	787.6
TOTAL FOCUSED, PHASE 1	7.9	67.6	50.7	30.6	0.0	0.0	156.8
TOTAL FOCUSED, PHASE 2	0.0	0.0	0.0	71.0	225.0	225.0	521.0
TOTAL LONG-TERM, HIGH PAYOFF	20.5	9.3	8.6	15.6	25.7	30.1	109.8
RLV FLIGHT DEMONSTRATION PROGRAM	0.0	24.0	49.0	76.0	85.0	100.0	334.0

Mr. SENSENBRENNER. Thank you, Dr. Mansfield.

Colonel Payton, do you want to add anything to that?

STATEMENT OF COL. GARY PAYTON

Col. PAYTON. Mr. Chairman, just a personal note. A little over ten years ago, I flew on the Shuttle. All three of the companies that are at the table here today were part of that flight.

The Shuttle is a superb system accomplishing a very broad range of missions. However, it is old. When I flew on the bird on Discovery over 10 years ago, the design was 13 years old then. Technology has improved in the aerospace industry and, while the Shuttle is a superb program, it is intensely complex and is too expensive for our future.

The job of NASA over the next four years is to prove new technologies that are applicable to the space launch business, and let the full-scale development decision that we make at the end of the decade, let that decision be based on sound test results and firm flight tests and ground test experience.

So that is the fundamental objective we have for the RLV program. It is a little bit different from what the Shuttle did in its early gestation, but our objective for the next four years is to demonstrate the newest technologies in the relevant environments, and then embark upon the full-scale development of the operational bird. Thank you.

Mr. SENSENBRENNER. Thank you, Col. Payton.

Next up is Mr. Minor of Rockwell International. Bob?

STATEMENT OF MR. ROBERT G. MINOR, PRESIDENT, SPACE SYSTEMS DIVISION, ROCKWELL INTERNATIONAL

Mr. MINOR. Good morning, Mr. Chairman, and Members of the Subcommittee:

I am pleased to respond to your invitation to provide information on this very important program. Rockwell's heritage in space speaks for itself, and I will not elaborate.

We believe that the Reusable Launch Vehicle Program is the right program to develop the next generation of space transportation systems. We have been working to establish the technical grounds for such a program for some years.

We support the current Presidential space transportation policy which gives NASA the lead role in the development of reusable launch systems because it provides the best hope of significantly reducing the cost of space operations to users.

We also believe that the program decision criteria developed by NASA, OMB, and OSTP, provide the right framework to develop the program, and to focus the business investment decisions to both industry and government.

Single-stage-to-orbit is an exciting concept. We believe it is technically feasible, and it provides great promise of dramatically cheaper space transportation.

It is also very challenging. To meet the challenge we must succeed in five fundamental areas:

Greatly reduce the weight of our structure, including the fuel and oxygen tanks;

Increase the thrust-to-weight of our engines;

Integrate and test these technologies in a very efficient vehicle design; and

Greatly lower the acquisition costs and recurring operational costs; and, finally,

Develop a viable business plan that accommodates the market, the risk, the cost, and the required return on investment.

The X-33 Program is needed to meet these challenges. It will provide the technical data necessary for a full-scale development decision in 1999.

The RLV program is fundamentally different from past space technology programs, for it is planned to support a business investment decision, not just a technical performance or feasibility decision.

The focus of the X-33 program is on an overall venture/risk reduction and reducing the cost of operations in space, as well as launch system performance.

The purpose is to provide the insight and confidence for our shareholders and investors to move forward with this venture.

If we can further reduce RLV program risk with the X-33 program, we will be able to provide lower costs to our users.

You asked that we identify ways in which Congress can help.

You have already been a big help in supporting the current cooperative agreement between government and industry. It has proved to be an innovative and effective way for the Nation to tackle the problem of low-cost access to space.

You could provide additional help with funding government markets and risk sharing. We suggest for your consideration two changes in the funding to further reduce risk.

First, the current funding profile is backloaded. A large percentage of the funds are in 1999 after the major expenses of development and manufacture of our test vehicle.

We have suggested an improved funding profile in our written testimony.

Second, we recommend a second backup flight test vehicle. Our experience on X-15, X-29 and X-31 show this to be a wise investment in the possible case of a loss of test vehicle.

We also recommend Congress give government agencies and departments authority to commit to future usage of an RLV. We must have a firm market to secure private funding.

Congress can also assist with third-party indemnification, licensing, and other regulatory issues including environmental considerations.

This completes my oral testimony. I thank you for the opportunity to address the subcommittee this morning.

[The prepared statement of Mr. Minor follows:]

Testimony by Robert G. Minor, President
Space Systems Division, Rockwell International
before the Subcommittee on Space and Aeronautics for a
Hearing on the Reusable Launch Vehicle (RLV) Program
November 1, 1995

Good morning Chairman Sensenbrenner and Members of the Subcommittee. I am pleased to respond to your invitation to provide information on a very important program. Rockwell International has been a pioneer in space activities, and is committed to improving space transportation for government and commercial users. We are very proud to be part of the nation's accomplishments, including key roles in the Apollo and Space Shuttle programs. We are also very well aware of the problems and inefficiencies of the current way of doing business for space transportation. We believe the Reusable Launch Vehicle (RLV) program is the right program to develop the next generation space transportation system, and we have been working to establish the technical basis for such a program for some years.

We support the current Presidential space transportation policy which gives NASA the lead role in the development of reusable launch systems technologies, because it provides the best hope of significantly reducing the cost of space operations to users. When starting the program, NASA agreed with OMB and other administration groups to provide key technical and programmatic decision criteria which have to be met before proceeding into the demonstration phase (Phase II), and the full scale development phase (Phase III) of the RLV program.

These decision criteria and the planned RLV program are well thought out, and provide an excellent framework for both industry and government, to gather the insights and confidence needed to establish the go-ahead decision for the demonstration phase (Phase II), and for the investment decision by both government and industry for full scale development (Phase III). This program is a pivotal step in the move for further commercialization of the space industry, and these decision criteria and the supporting technical demonstration are the key in establishing our readiness to make these decisions.

The RLV program is fundamentally different from past space technology programs, as it is planned to support a business investment decision, and not just a technical performance or feasibility decision. The focus of the RLV program is upon overall venture risk reduction, and reducing the cost of operations in space, as well as launch system performance. The purpose of the RLV program is to provide the insight and confidence for our shareholders and investors to move forward with this venture.

In the rest of my statement, I will focus on the four key issues that you raised in your letter of invitation.

1. UNDERSTAND THE TECHNOLOGICAL RISK REDUCTION PHASE OF THE RLV PROGRAM IN TERMS OF: A. COST OF X-33 PROGRAM; B. TECHNICAL DIFFICULTY OF PHASE II; AND C. KEY PARTICIPANT'S ROLE UNDER THE COOPERATIVE AGREEMENTS.

The risk reduction program leading to a decision for commercial development of a Reusable Launch Vehicle (RLV) program consists of two phases. Phase I extends from Spring '95 to July '96. It consists of both the technology and a requirements definition and design task. It is funded by both government and industry via a cooperative agreement. We are funding about 50% and NASA is funding about 50%.

In Phase II, we will develop, build, and test the X-33 flight vehicle, which is a scaled design of the operational RLV. The test program will include both ground and flight test activities to demonstrate the technical feasibility of a Single Stage to Orbit (SSTO) vehicle concept. In parallel, there will be a continuing design integration task to ensure the ultimate RLV concept continues to direct the test objectives and profit from the technology test results. Phase II is scheduled to begin in July '96 and extend through the end of the decade, with the first flight in March 1999

Projected government funding for X-33 Phase II program is about $1B. Parallel industrial investments have not yet been finalized, and will depend upon the projected risks in the program as we prepare our specific Phase II proposal, and upon the government's plans and commitments for Phase III. We are managing the program as a design-to-cost activity, where we have allocated the available budget to the highest risk issues. We will manage to the available funds, government and private, and update our risk assessment with our progress. Our objective is to reduce the risk to add confidence to our acquisition and ops cost projections and to qualify for "industrial grade" financing vs. the more expensive, and limited "venture" capital.

The X-33 risk reduction phase of the RLV program is critical to meeting our twin goals of single-stage-to-orbit and low cost of operation. The most important and challenging tasks are as follows:

a. Design and integration of a portfolio of technologies into an efficient and operational system is a very difficult and pivotal task requiring a flight vehicle. Phase II, the X-33 program, tests the specific requirement for the technologies; develops the compromises and interfaces between the technologies; and defines the margins and robustness of the flight vehicle. The system is then operated to establish the performance and problems of these technologies in a realistic flight and operational environment, providing confidence in the design and operational approach. These issues are addressed throughout the design, development, and test cycle. The lessons gained from the X-33 flight vehicle in design integration concerning interfaces, component requirements, margins, robustness, and costs will validate and calibrate the design and analytical prediction tools and cost models for a similar but larger vehicle, the RLV.

b. To meet the demanding performance objectives of Single State to Orbit, we must greatly increase the vehicle mass fraction (the percentage of fuel to total vehicle weight) and the

engine thrust to weight. To increase the mass fraction we must develop a very lightweight vehicle. At the same time, this lightweight structure must be reliable, reusable and highly operable in expected flight and operational environments.

The most challenging step is to develop a graphite epoxy tank for liquid hydrogen fuel. The X-33 tank will prove out the design and manufacturing processes by designing and building a scaled replica of the RLV tank and flight testing the tank in realistic operational environments.

We are developing an aluminum-lithium oxygen tank with a newly developed joining technique called friction-stir welding. Such a tank will result in a much lighter, less costly tank than existing systems. We are also developing graphite composite components for wings, inter-tank and engine thrust structure to reduce weight. These structural components will be subjected to extensive ground and flight tests to reduce risk for the RLV.

Besides building lighter and stronger structural elements to meet the required vehicle mass fraction, we must also increase the performance efficiency of the rocket engine to achieve SSTO capability, and reduce its operational costs. But coupling a new rocket engine development to a new vehicle structure greatly increases the risk of a technology development and demonstration program. To reduce the technical risks of this area for the RLV and X-33 programs, we have defined a parallel ground test program to demonstrate the main propulsion rocket engines for the RLV.

The X-33 will use the proven Space Shuttle Main Engine (SSME) to provide its propulsion to demonstrate the RLV structural and operational technologies through flight test. In parallel with the flight test program, we plan a ground test program to develop and test a prototype main engine for the RLV. This liquid oxygen/liquid hydrogen powered main engine for the RLV will build upon the high in-flight reliability of the Space Shuttle Main Engine with component-by-component upgrades to increase the thrust, reduce the weight, and greatly reduce the operational costs.

c. A major focus of the risk reduction program is to reduce the cost of operations and the turnaround time for the RLV. Our target is less than $20M per flight and a seven-day turnaround. In addition to the engine upgrade work, our program includes the development and demonstration of a far tougher, lower maintenance thermal protection system than used on shuttle; and extensive use of vehicle health monitoring. It also requires a design for maintenance and operations, which includes "aircraft-like" horizontal maintenance and standardized payload containers for parallel processing and low cost integration for the customer. A major objective of the X-33 flight test program is to demonstrate and improve our operational support procedures.

In addition to the technical hardware components, an important product of these risk reduction tasks is the improved management and technical processes needed to greatly reduce the investment cost for the RLV

Rockwell, as prime contractor, is managing the Phase I effects of our team and will manage the X-33 Phase II program. This includes the business planning, design, manufacture, test, and program integration functions. Our major industrial team member is Northrop-Grumman, who brings key skills for composite structures and vehicle operations.

NASA and the Air Force are also major participants and team members, working with us as subcontractors and investors, conducting research and tests on our key technology tasks and providing valuable experience and analytical support for our design tasks. We currently have 71 separate task agreements defined and in work by the government personnel in direct support to our program. The relationship with these government agencies is new for both the government and our design team, and is working very well. We plan to continue to "subcontract" to the NASA centers and Air Force laboratories for Phase II and Phase III of the program.

2. *DETERMINE WHETHER SUFFICIENT FUNDING HAS BEEN REQUESTED BY NASA TO ACHIEVE THE LEVEL OF RISK REDUCTION CONSIDERED NECESSARY BY INDUSTRY PARTNERS; AND WHETHER ADJUSTMENTS IN THE PROMISED FUNDING CURVE ARE NECESSARY OR NOT.*

The funding currently planned by NASA to support Phase II will reduce the technical risk sufficiently to meet the decision criteria and to make a FY-99 decision to develop a full scale RLV. We will have developed the necessary technology, and have quantified the risk and the cost of both system investment and recurring operations. But this is a high risk program, with a demanding schedule, and changes to the funding profile will be needed to assure we meet the expected flight schedule. Additional funding would further reduce the risk and the cost of Phase III, with a subsequent reduction in the future price of RLV operations.

We recommend consideration be given to three adjustments to the current plan. First we recommend the planned funding profile be adjusted. The projected funding profile should be adjusted to maintain the flight schedule. An efficient, quick, design and development program would require a greater percentage of funds in early years to support a demonstration by 2000. The current government projected profile places the greatest percentage of funds in the later months, when most of the design and manufacturing work is expected to be completed -- and hence is not efficiently spread for a fast track development and demonstration program. An efficient design and development program requires a greater percentage of funds in the early years. Specifically, we recommend an adjustment of the currently projected funding change as follows:

	FY96	FY97	FY98	FY99	FY00	Total ($M)
Current Funding Profile	113.0	197.9	340.4	359.8	N/A	$1011.1
Revised Funding Profile	113.0	314.0	406.9	172.5	4.7	$1011.1
Difference ($M)		+116.1	+66.5	-187.3	+4.7	$ 0.0

Second, we recommend consideration be given to a back-up, second, flight vehicle. With the planned ground based technology work, current funds will only fund one flight vehicle. Our team's experience with past X-vehicles such as the X-15, X-29, and X-31, suggests additional

funds would be a wise investment for a second vehicle in case of unexpected test failures. Experimental, envelope-pushing test programs are the purpose of X-vehicle programs, and we must be aware of the risks of such programs

Our third recommendation is to consider additional funds for back-up technology approaches. We believe our design approach is sound and doable. However, with so much at stake, it would be prudent to invest some funds in selected back-up technologies which could provide alternate solutions to our most critical components. The most critical components are those that most influence the key RLV technology objectives: thrust to weight and reliability of engines; mass fraction; and the operability and reliability of subsystems. The selected components as best candidates for back-up technology efforts are the cryogenic main engine, liquid hydrogen tank, liquid oxygen tank, and the thermal protection system. Candidate alternative technologies would include high pressure liquid oxygen- rich pumps, or alternative designs for the light weight, reusable graphite epoxy liquid hydrogen fuel tank. These "back-up" technologies should be managed as part of the prime X-33 program. We are working with NASA to define the most promising projects.

3. QUERY THE INDUSTRIAL PARTNERS IN THE RLV PROGRAM WITH RESPECT TO THEIR ABILITY TO PROCEED WITH PRIVATE DEVELOPMENT OF THE RLV LAUNCHERS, AND DETERMINE UNDER WHAT TERMS AND CONDITIONS THESE FIRMS WILL BE ABLE TO PRIVATELY FINANCE FULL-SCALE DEVELOPMENT.

If the X-33 program, and the supporting ground technology demonstrations are successful, Rockwell, with its teammate Northrop Grumman, has the ability, and will proceed with private development of an RLV system -- If this decision makes good business sense.

We must establish that we can structure an acceptable venture with our shareholders and investors, and with key customers -- and that such a venture is compatible with the legal, and regulatory environment. We see private financing of a RLV development as practical if the venture's risk is reduced to an industrial investment level, and if the US government, as the largest single near-term customer, can participate and can provide assurance its usage is available if we provide a superior product.

The key factors which define the business venture decision are market, operating margins, venture risks, and projected returns on investment. The technical risk reductions proposed (Phases I and II) will greatly reduce the risk of the RLV investment for the acquisition cost, and the recurring operations cost. Markets for space transportation exist and we can capture them, if we offer a superior product in price, service, reliability, availability, and ease of use.

The remaining risks (real and perceived) will in turn define the required rate of return necessary to attract sufficient funds to finance the acquisition program -- with the constraint that if the residual risk is too high, the number of investors may be too low to fund the program. We believe today with the projected market—and if cost per launch is reduced to about $20M (FY95$), the acquisition cost to less than $10B, and the perceived risk to industrial level (with cost of money less than 20%)—we have a viable venture with a some government risk sharing. We believe the government sharing could take several forms and would be more than repaid in

the reduced cost of space launch. We are working hard today to refine our cost estimates, and reduce the venture's risk. We will continue to update our estimates as we work through the Phase II program, and are planning to use the Phase II program to validate our cost and operational estimates.

The market is a very important consideration to this venture, as it establishes our revenue projections. Looking at near-term existing markets, over 1/2 of the potential planned missions are from the US government. The US government is by far the largest, initial single customer we see. During the critical early years of operation, when we are establishing that we can pay back our investors, we must be assured the US government will commit its market to us if we provide a superior product.

Looking to longer term markets -- the "New Horizon" markets -- we believe commercial usage will dominate the usage of the system. The availability of low cost, highly reliable, and easy-to-use space transportation offers a huge potential for new markets. But it will take time for these entrepreneurs and new ventures to be assured of our success, and to invest and facilitate to take advantage of our new capabilities. We look to these new markets as the ultimate users of this system, and believe our ultimate financial success will be through our success in generating new markets and opportunities for free market business. But we must justify the investment and protect our investors based on the near-term markets alone.

A secondary, but potentially very important factor in venture viability is establishing that such a venture is compatible with the legal, and regulatory environment. We will work with NASA and the Congress to help define appropriate legislation to both protect the public and to create a favorable environment for commercial space investment and space operations.

4. DETERMINE WHETHER THE RLV PROGRAM BEING EXECUTED BY NASA UNDER THE COOPERATIVE AGREEMENTS COULD INADVERTENTLY BECOME A TRADITIONAL, NASA PAYS ALL PROCUREMENT, AND IDENTIFY STEPS FOR CONGRESS TO FOLLOW IN AVOIDING SUCH A SCENARIO.

Yes, it is possible the RLV program could revert to a traditional government-funded and managed program if we are not careful.

The current RLV definition and technology development activities are providing a promising demonstration of how NASA and industry can work together to keep this from becoming a traditional "NASA-pays-all" procurement. NASA is currently managing the program very effectively and efficiently with a small "can-do" staff. Operating on both Industry and NASA financing, NASA is working with us as a team-member and subcontractor. Industry is taking the lead in setting the requirements, establishing the technical baselines, and defining the product to be built. Most of the NASA and AF laboratory personnel supporting this program are working on specific products for industry and not as bureaucratic oversight. But to ensure that we do not revert back to the "old ways of doing business", we believe the following steps are essential:

a Industry must have the full responsibility, authority and accountability to manage and to make the decisions necessary for a commercial program.

b. Industry must be permitted to design the system to the "sweet-spot" in the market (in terms of payload weight, size and support services), and not be dictated by a government specification. We recognize the role the US government plays in the space market -- as the single largest current customer. But to provide a viable commercial product, our design considerations must be driven by investment and market demand, instead to an "outlying" maximum mission requirement. Our current assessments indicate we can accommodate over 90% of the government's payloads while designing for the business-derived best system.

c. Key government issues affecting industry willingness to invest in Phase III should be resolved prior to Phase II. While we project commercial users to grow to dominate the overall market in the long term, in the short term we need a firm commitment from the dominant customer for space transportation services. Such a commitment is needed to provide a market base to justify a RLV investment to our shareholders and financiers. This must be resolved quickly, as the existence, or non-existence, of such a commitment is a major determinant of the level of our investment in the next phase of this program,

Congress can greatly assist in these matters with the following actions:

a. Provide NASA the authority to provide a guaranteed market floor.

b. Government should also consider risk sharing in Phase III. This could take several forms to include co-investment or government investment as a "limited partner." The potential of new markets arising from expanded space access is huge, and there will be large economic potential to the US economy from low-cost, routine space access, with dramatic impacts upon international competitiveness of US businesses. Risk sharing could also include pre-negotiated agreements for launch services and progress payments toward these services. Government investment in an RLV venture would have big leverage to further drive down the cost of operating an RLV for both government and commercial users, and with significant returns to the nation.

c. Launch indemnification and licensing regulations for reusable launch vehicles need to be enacted to reduce the potential risk to commercial RLV operators, in a similar manner as was done for commercial expendable launch vehicle operators. The X-34, which we are developing in partnership with NASA and Orbital Sciences Corporation, is pioneering this regulatory regime.

d. Other regulatory issues, including environmental considerations must also be addressed. We need to ensure our investors there are no "show stoppers" preventing an investment from being realized, and recognize the need to ensure that we both protect the public safety, while creating an environment for commercial space operations.

I appreciate this opportunity to testify before the Space and Aeronautics Subcommittee on this very important topic. NASA and industry are blazing new ground in the cooperative development and commercialization of a revolutionary space transportation system. The successful implementation of our joint NASA-industry plans for the X-33 and RLV programs will return this nation to a preeminent position. Continuing support and assistance of the Congress will be critical to the success of these innovative programs.

Mr. SENSENBRENNER. Thank you very much, Mr. Minor.

Next up is Mr. Ordahl from McDonnell Douglas.

Chuck?

STATEMENT OF MR. CHARLES A. ORDAHL, VICE PRESIDENT-GENERAL MANAGER, NEW SPACE AND DEFENSE PROGRAMS, McDONNELL DOUGLAS AEROSPACE

Mr. ORDAHL. Mr. Chairman, Members of the Committee:

I represent the McDonnell Douglas DC-X, the DC-XA, and the McDonnell Douglas/Boeing X-33 RLV program.

Let me begin first by congratulating you, Mr. Chairman, and the Committee for your long standing support, and especially for authorizing the full 1996 request for the RLV program.

We believe development of the X-33 flight demonstrator for SSTO technologies is the appropriate next step in evolving the Nation's capability to be a world leader in the launch vehicle industry.

Full exploitation of the scientific, technological, and commercial benefits of space is dependent on continued reduction in the cost of launch services.

These principles have guided the evolution of our Delta expendable launch vehicle product line consistently for over 30 years, but we recognize that there is a limit to the economies and operational improvements that can be achieved on expendables.

We believe that ultimately there will be a fully reusable launch vehicle system capable of placing payloads in orbit at a fraction of the cost of today's expendables.

We have already proved that the concept of a fully reusable system on a smaller scale. In 1991 we entered into a contract to build the DC-X single-stage rocket. It was the world's first fully reusable vertical takeoff, vertical landing rocket.

We faced a tight schedule, budget limitations, and we applied a highly streamlined management process using an integrated government/industry development team.

This "radical" new vehicle was designed and built in less than 20 months.

Following that, we performed a flight test program that included a series of eight vertical takeoff/vertical landing missions. On each mission we performed successively more complicated maneuvers.

One of the main objectives was to prove the feasibility of airline-type operations on a complex, cryogenically fueled rocket vehicle.

The result was a vehicle that required a flight management crew of only 3 people and a ground support crew of less than 15 engineers and technicians.

However, with the limited scope of the DC-@ program, we could only address—we could not address the full range of technology issues needed to prove the feasibility of a full-scale SSTO RLV.

DC-X is now being modified under NASA contract to introduce new technologies to bring us one step closer to that goal.

We have just completed the composite liquid hydrogen tank, and also the advanced technology aluminum-lithium alloy liquid oxygen tank. These high strength, lightweight components will be introduced into a new vehicle called the DC-XA which will begin a series of flight tests in the spring of 1996.

However, still with the performance limitations of the DC-X and the XA, we cannot fully and adequately test the effectiveness and durability of such things as the thermal protection system, and we cannot really adequately evaluate the full scalability of our design solutions and operational concepts to the full size RLV.

That is why the next step, the X-33, is necessary.

The incremental path of building and testing first the DC-X, the -XA and then the X-33 is a prudent path. The "fly-a-little, test-a-little, learn-a-lot" approach is the right approach for this program.

The X-33 will allow both government and industry to evaluate the state of RLV technology readiness, to examine the economics of the RLV construction and operations in detail, and to make an informed decision on whether or not to proceed with the full-scale RLV development.

There are major potential benefits for both government and commercial users. With sufficient versatility combined with the achievement of truly low-cost operations, there is certainly also the possibility of opening new commercial markets and providing a new class of military launch services somewhere in the future.

With that, I would like to say thank you, Mr. Chairman, for allowing me to present these remarks from McDonnell Douglas on this critically important program.

[The prepared statement of Mr. Ordahl follows:]

Testimony of

Charles A. Ordahl
Vice President-General Manager
New Space and Defense Programs
McDonnell Douglas Aerospace

before the

Subcommittee on Space and Aeronautics
Committee on Science
United States House of Representatives

Wednesday, November 1, 1995

Mr. Chairman and Members of the Committee.

My name is Charles A. Ordahl. I represent the McDonnell Douglas DC-X and DC-XA teams and the McDonnell Douglas/Boeing X-33 Reusable Launch Vehicle team. I appreciate this opportunity to address the subject of X-33 and RLV.

Let me begin by congratulating you, Mr. Chairman, and the Committee for your long standing of support for the single-stage-to-orbit (SSTO) technology development and demonstration program, and for authorizing the full FY96 request for the RLV program.

We believe a decision to proceed with development of an X-33 flight demonstrator vehicle for SSTO technologies is the appropriate next step in evolving the nation's capability to be a world leader in the launch vehicle industry. Full exploitation of the scientific, technological and commercial benefits of space is dependent on continued reduction in the cost of launch services and continued improvement in the reliability and ease of access to space. These principles have guided the evolution of our Delta launch vehicle product line consistently over more than 30 years. Since the first launch of Delta in 1960, we have dramatically increased payload lift capability while continually improving vehicle reliability and substantially reducing the cost per pound of the launch services. We are dedicated to continuing on this path. But we recognize that there is a limit to the economies and operational improvements that can be achieved with expendable launch vehicles. We believe that, ultimately, there will be a fully reusable launch vehicle system capable of placing payloads in orbit at

a fraction of the cost per pound of today's expendable launch vehicles. These RLVs will be capable of operating more like a commercial airliner with the ability to fly again within as little as 2-3 days after landing from a previous mission. They will be designed to be easily serviced and maintained. They will be capable of dozens of missions without a major overhaul.

We have already proved that the concept of a fully reusable system is feasible on a smaller scale. In 1991, we entered into a contract with what is now the Ballistic Missile Defense Organization to build the DC-X single-stage rocket. It was the world's first fully reusable vertical take-off and vertical landing rocket. Faced with a tight schedule and budget limitations, we applied a highly streamlined management process using an integrated government/industry development team. With our "rapid prototyping" method of new product development, this radical new vehicle was designed and built in less than 20 months. Following that, we performed a test program that included a series of 8 vertical take-off/vertical landing missions. On each mission we expanded the flight envelope to fly higher and faster, and performed successively more complicated maneuvers. One of our main objectives was to prove the feasibility of airline-type operations with a complex, cryogenically fueled rocket vehicle. We built a sophisticated flight and operations controls system using the latest techniques in automation and software development technology. We also incorporated highly efficient aircraft-type maintenance and servicing features throughout the total system. The result was a vehicle that requires a flight management crew of only 3 people and a ground support crew of less than 15 engineers and

technicians. Although this only a one-third scale vehicle, we concluded from our flight and ground tests, that it is feasible to build a full scale RLV that can be routinely and safely operated using only a handful of personnel.

However, with the limited scope of the DC-X program and the size of the vehicle we could afford to build, we could not address the full range of technology issues needed to prove the feasibility of a SSTO RLV. We did prove, however, that an X-type vehicle is an outstanding test-bed for evaluating a wide range of technology options in a realistic set of flight profile and ground operating conditions.

DC-X is now being modified, under NASA contract, to introduce new technology that will bring us one step closer to verifying the feasibility of an RLV. We have just completed the construction of an all composite material liquid hydrogen tank and an advanced technology aluminum-lithium alloy liquid oxygen tank. These high strength, lightweight components, along with several other advanced technology components, will be assembled to create the DC-XA which will begin its series of flight tests the spring of 1996.

Some of the most difficult technical hurdles are still ahead of us. With the performance limitations of DC-X and DC-XA, we cannot adequately test the effectiveness and the durability of the thermal protection system, and we cannot adequately evaluate the scalability of our design solutions and operational concepts from the small size of the DC-X/DC-XA to the full size RLV. This is why the next step, the X-33, is necessary.

The incremental path in building and testing DC-X, DC-XA and X-33, is a prudent path. The "fly-a-little, test-a-little, learn-a-lot" approach employed in the nation's proud history of X-plane flying laboratories is a proven approach for demonstrating new technologies and concepts.

The X-33 program will allow both government and industry to evaluate the state of RLV technology readiness, to examine the economics of RLV construction and operation in detail, and to make an informed decision on whether or not to proceed with full-scale RLV development.

The RLV offers the potential for a dramatic reduction in the cost of launch and cargo retrieval services currently being performed by the space shuttle. It is important that the RLV be designed to accommodate these mission needs. A vehicle sized to meet these requirements could serve the commercial market under a wide range of customer payload requirements now being served by expendable launch vehicles. Thus, there are major benefits for both government and commercial users. With sufficient versatility, combined with achievement of truly low cost operations, there is also the possibility of opening new commercial markets and providing a new class of military launch services.

In closing, I thank you, Mr. Chairman, and the committee for this opportunity to express the views of McDonnell Douglas on this critically important program to our nation's future in space.

Mr. SENSENBRENNER. Thank you, Mr. Ordahl.

Next up is Jack Gordon of Lockheed Martin.

STATEMENT OF MR. JACK GORDON, PRESIDENT, LOCKHEED MARTIN SKUNK WORKS, VICE PRESIDENT, LOCKHEED MARTIN CORPORATION

Mr. GORDON. Good morning, Mr. Chairman, and Members of the Subcommittee:

I am president of the Lockheed Martin Skunk Works, an operating company of the Lockheed Martin Corporation.

Our company is presently leading one of the three industry teams participating in the NASA X-33 Design Competition.

We are drawing on the vast experience of the Lockheed Martin Corporation that has made some significant contributions to space programs, providing more than one-half of all U.S. payloads placed in Earth orbit, and more than 60 percent of all launches.

The Skunk Works for more than 50 years has been recognized for developing cutting edge technology rapidly and cost effectively using unconventional management methods that cut through layers of supervision and red tape.

This approach has resulted in such innovative aircraft systems as the U-2 and SR-71 Reconnaissance Airplanes, and the F-117A stealth fighter.

For the past three years our team has been working to apply our methods and technical skills to a concept for a new type of Reusable Launch Vehicle that will use an aircraft like design approach to operating and maintaining the vehicle.

Our objective is to produce a system that provides affordable access to space.

Our company and its team members believe that the technology required for an efficient, cost-effective RLV is challenging but obtainable.

Our philosophy is to harvest and integrate existing high-potential technologies that have evolved in recent decades.

Among the technologies we anticipate using are large, lightweight composite structures such as those used in some of our corporation's newest fighter aircraft programs. We are planning to have a wingless lifting body re-entry vehicle using concepts tested by the Air Force and NASA prior to the development of the Space Shuttle Orbiter.

Also, we expect to make use of a fully integrated linear aerospike engine developed by Rockwell's Rocketdyne.

We plan to incorporate graphite epoxy composite tanks to hold the liquid hydrogen and liquid oxygen propellants.

We are working with Rohr Corporation to make use of its expertise in lightweight robust thermal protection systems. And, Allied-Signal is providing state of the art functional system support.

I would like to acknowledge that NASA has been an integral part of our team providing analysis and feedback.

We also have devoted considerable attention to the financial and business aspects of developing a new RLV and placing it into service.

It is clear to everyone that, to be successful, a new RLV must leapfrog existing systems and reduce by an order of magnitude what it costs today to place payloads into orbit.

It has also become clear to us in discussing this topic with investment experts and financial analysts that there are obstacles to be overcome in order to make a new RLV an attractive prospect for private financing.

Assurances of an ongoing market for launches are fundamental to the investment community. We believe that it will be necessary for specific launch commitments to be made by the government before RLV development with private sector funding can begin in Phase III of the current NASA program.

It is our view that RLV development will require on the order of $5 billion.

The present plan also requires industry funding during Phase II Subscale X-33 development. If launch guarantees and indemnification for the development costs are not forthcoming for Phase III RLV development, the presently envisioned scale of industry funding during Phase II is potentially too large for industry to consider the investment commensurate with the risk.

There has been a recent request for costs for a second X-33 vehicle and development of alternative technologies. We strongly endorse approval of such funding request to ensure adequate development resources, and to reduce RLV risk to a workable level with additional emphasis on full-scale ground tests of the critical components.

Because the financial community believes private investors will not provide RLV developmental capital without a guaranteed launch market, and because investors perceive that the technical risk requires a larger scale RLV flight and demonstration program, we would recommend that a special board be convened.

This board would have representation from the appropriate financial institutions, the industrial partners, and government representatives. Its task would be to develop a workable financial solution.

We are convinced that government launch savings from an RLV program will be dramatic. This merits strong government guarantees and perhaps more government funding than is contemplated in current plans.

Finally, we believe a Skunk Works'-led team of industry and NASA participants can produce a robust RLV system that will allow the United States to recapture the space launch market.

With that, I thank you, Mr. Chairman, and Members of the Subcommittee, for the opportunity to participate in these proceedings.

[The prepared statement of Mr. Gordon follows:]

Testimony by

Jack S. Gordon
President
Lockheed Martin Skunk Works
Vice President
Lockheed Martin Corporation

Before the

U.S. House of Representatives
Committee on Science
Subcommittee on Space and Aeronautics

Washington, D.C.

November 1, 1995

Mr. Chairman and Members of the Committee:

On behalf of the Lockheed Martin Corporation, I am pleased to have this opportunity to testify at this hearing on the Reusable Launch Vehicle (RLV) Program.

1. Introduction

Lockheed Martin is prime contractor for the Titan, Atlas and LLV series of launch vehicles. At Kennedy Space Center, Lockheed Martin has processed 62 of 72 space shuttle launches. Over the last four decades, this corporation has provided more than one-half of all United States payloads placed in earth orbit. For much of that time, the United States launched 100% of the free world's vehicles into space. Lockheed-Martin vehicles to date have accounted for more than 60% of those launches.

During the past two decades, the U. S. share of the global launch market has fallen from 100% to approximately 30% due primarily to the evolution of more modern Western European, Russian and Asian space launch systems. This market share could erode further in the coming decade as numerical restraints are lifted from offshore systems. In addition, U. S. launch systems used for our own military and civil programs rely primarily on boosters derived from 1960's and 1970's technology. The result is that responsiveness and affordability are far from what would be possible with more modern launch systems.

It is vital to United States' interests to recapture its leadership in space launch capability. Key to this leadership is "affordable access to space."

Now is the time for the U. S. to develop a state of the art Reusable Launch System that leapfrogs incremental expendable technology improvements. The EELV Program is providing the near-term vital incremental expendable vehicle technology improvements necessary to reduce launch costs and improve reliability of present systems. An RLV Program will complement the planned EELV systems and enable us to re-establish our leadership in space exploration and ensure that our strategic and commercial needs are affordably met. Further, this uniquely American

capability for RLV development can lay the foundation for future decades of American launch services which will contribute greatly to our balance of trade.

2. The Skunk Works' Vision for a New Approach

The Lockheed Martin Skunk Works (please see Attachment No. 1) has for more than three years been at work on a design concept for a new type of Reusable Launch Vehicle (RLV). For more than half a century, the Skunk Works has built a reputation for developing cutting-edge technology rapidly and cost effectively, using unconventional management methods that cut through layers of supervision and red tape. This approach resulted in such systems as the U-2, SR-71, and the F-117A stealth fighter. The RLV Program is an equally difficult challenge. The Skunk Works was assigned the RLV project within Lockheed Martin for these reasons.

The early Skunk Works RLV concept emphasized keeping costs low by innovatively applying existing technology. It also focused on a competitive, ground-based risk reduction program leading to the full-scale development of an RLV that uses an aircraft-like design approach to operating and maintaining a reusable launch vehicle. It was anticipated that the developmental cost for two vehicles with this approach would be on the order of $5 billion and take approximately five years.

Given the current budget constraints, initial studies were conducted to determine the financial viability of a privately developed RLV. Discussions in 1993 with investment analysts and other members of the financial community indicated that private funding might be available subject to three provisos: first, in order to attract private capital it would be necessary to provide government-backed launch guarantees. Second, in the event the government changed its mind during development such that guarantees would not be realized, the private RLV investors would be reimbursed for their investment. Third, private investors would expect the industrial RLV developer to make a significant investment in the partnership.

Our preliminary studies indicated that if a spending level on the order of the annual $2.5 billion currently projected to be spent on space shuttle launches were available, private funding of an RLV would be viable, allowing development costs to be

recovered in a reasonable time. However, this was conditioned upon a contained-cost, streamlined, development program in order to achieve an appropriate rate of return. It should be noted here that even under these conditions, the government would realize dramatic savings over the present launch systems.

The Skunk Works in 1993 began to form a team of companies to participate in the planning and design of an RLV that would meet the global need. The team's concept was and still is for a single-stage-to-orbit (SSTO) vehicle that could carry some 40,000 pounds of payload to low earth orbit and 25,000 pounds to the space station orbit.

3. The Current Approach

The current NASA Program Plan includes the development of a sub-scale, suborbital X-33 Demonstrator and RLV Technology Program. This phase is followed by a privately financed full-scale development of the RLV.

In establishing the X-33 design competition in the spring of 1995, NASA selected three companies, including the Skunk Works, to work under cooperative agreements. Each company heads a team of organizations (please see Attachment No. 2) working in Phase I of the competition, involving RLV concept definition and design of the X-33. This sub-scale vehicle is intended to demonstrate the technology required and to define a business approach for a 21st century commercial, reusable space launch system. Meeting the criteria set forth in the "OMB Directive," the government and industry team will make a determination about whether to proceed into Phase II X-33 demonstrations and later Phase III RLV development.

NASA has made significant improvements in its acquisition process. Joint program management and open communications between NASA and the participants represent positive changes over past practice. NASA and Lockheed Martin engineers are working side-by-side and NASA engineers are conducting tests and analysis in direct support of our concept as well as those of the other competitors.

4. The Necessary Technology is Achievable

The Skunk Works and its team members believe that the technology required for an efficient, cost effective RLV, while challenging, is attainable. A new RLV will benefit from the 30 years of technological progress that have taken place since the original concept for the Space Shuttle Transportation System.

The team's underlying philosophy is to "harvest" and integrate existing, high potential technologies that have evolved in recent decades (please see Attachment No. 3). Candidates include large, lightweight advanced composite structural concepts and manufacturing technologies developed for vehicles such as the Lockheed Martin F-22 and JAST/ASTOVL Fighter Aircraft Programs. They also include the wingless, lifting body re-entry vehicle concept (the Lockheed Martin X-24) flight tested by the Air Force and NASA prior to the development of the space shuttle orbiter.

The Lockheed Martin RLV concept incorporates a fully integrated linear aerospike engine developed by Rockwell's Rocketdyne Division. This unique design allows it to be fully integrated as part of the aero structure, saving considerable weight. Also planned for the team's vehicle are graphite epoxy composite liquid hydrogen and oxygen tanks developed by our external tank teams at Michoud, Louisiana. Our ability to develop these tanks was benefited greatly by research under the National Aerospace Plane Program performed by Lockheed Martin Tactical Aircraft Systems. Rohr, Inc. is a team member and an industry leader in design and manufacture of high temperature structural materials and thermal protection systems. Allied-Signal is providing state of the art vehicle systems for the concept.

While many vehicle systems (e.g., avionics) pose little or no technical risks, the following four areas of technology require a major risk-reduction program:

- reusable composite material cryogenic tank systems
- composite material primary vehicle structure
- reusable thermal protection systems

- efficient, reliable and reusable rocket propulsion systems

With suitable risk-reduction efforts on the above critical technologies, we believe that it should be possible to develop an RLV that will reduce the cost of launching payloads into space by an order of magnitude while achieving new levels of reliability and ease of operations and maintenance. It must be understood that our target here is a dramatic technology challenge but also necessitates a significant cost breakthrough as well.

5. Funding Considerations

At present, however, there are uncertainties within the financial community regarding private sector financing of RLV development due to the following factors:

- The government is pursuing multiple new concepts for both reusable and near-term evolved expendable launch vehicles. This creates uncertainties as to national priorities and dedication to the RLV concept.

- There has been a lack of progress toward achieving government launch commitments or finding other incentives to make private RLV development attractive. If private funding is to be available for Phase III full-scale RLV development, visible government support in the form of launch guarantees will have to be in place prior to the commitment of any significant levels of investments.

- It is also noted that the present plan also requires substantial industry co-investment during the Phase II sub-scale X-33 development. Without assurance of government launch guarantees and indemnification for Phase III development costs, the magnitude of industry cost sharing during Phase II is potentially too large for industry to consider the investment commensurate with the risk. This raises the prospects of a funding impasse for the Phase III RLV Program as currently planned.

- The current funding for the X-33 concept supports a single sub-scale technology demonstrator. Sub-scale flight testing in lieu of full-scale ground and flight testing may not adequately resolve the technical

uncertainties associated with a program of this scope and challenge. As a result, private investors may require a full-scale RLV flight before private sector financing can reasonably be expected.

Regarding sufficiency of funding, requests for costs of a second sub-scale vehicle and back-up technologies have recently been made. We vigorously endorse approval of such funding requests to assure adequate development resources and to reduce risks to a workable level. We also believe that additional emphasis should be devoted to full scale ground tests of critical components.

6. Conclusions

During recent discussions, the financial community has expressed the opinion that private investors will not be willing to provide RLV developmental capital because there is: (a) no guaranteed launch market and (b) a belief that the perceived technical risk requires a larger scale RLV flight demonstration or at a bare minimum, a far more comprehensive ground test program on critical full-scale components.

We recommend that a special board be convened with participants from the appropriate financial institutions, industrial partners and government personnel to develop a workable financing solution. The importance of financial institutions in this process cannot be overemphasized. We are trying to conceive a paradigm shift and their participation is critical.

We are convinced that government launch savings from an RLV Program are dramatic. These savings merit government launch guarantees and indeed are a prerequisite for a privately developed RLV. Based on our current assessment of the investment community, it is possible that more government funding may be required than is contemplated in current plans.

Assuming that financing issues can be satisfactorily addressed including consideration of the relative costs of government direct funding vis-à-vis commercial financing backed by indemnification, the Skunk Works Team (please see the list of participants shown in Attachment No. 2) looks forward to the challenge of developing a reusable launch system. While many risks are to be faced

and resolved, they are no greater than those we faced in developing the SR-71 in its era. In that development, we started without an engine, without processes for manufacture of titanium parts, and without high temperature fuel, hydraulic fluid and composite materials. Despite those obstacles, a streamlined Skunk Works and Government Team achieved first flight in 31 months and dramatically impacted military operations for the next three decades. We believe a Skunk Works led Industry/NASA Team can produce a robust RLV system that will allow the United States to recapture the space launch market with great long term benefits.

Attachment 1

LOCKHEED MARTIN

Background information:
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LOCKHEED MARTIN SKUNK WORKS

Headquartered in modern facilities at Palmdale, Calif., Lockheed Martin Skunk Works is dedicated to developing, producing and supporting special purpose, high-technology aircraft and systems. It also specializes in rapid prototyping and carrying out classified programs with short production runs.

Formerly called Lockheed Advanced Development Company, the organization received its current name in May, 1995, soon after the merger of Lockheed and Martin Marietta Corporations. Since its founding in 1943 as the Advanced Development Projects unit of Lockheed, the organization has used the nickname Skunk Works, adopted by employees from a popular comic strip of the 1940s, "Li'l Abner."

The Skunk Works has established a worldwide reputation for a series of innovative, record setting aircraft. Its first project in World War II resulted in the F-80 Shooting Star fighter, America's first production jet aircraft. It came from the work of a small engineering and manufacturing team at Burbank, Calif., led by renowned aircraft designer Clarence L. "Kelly" Johnson, founder of the Skunk Works. In the 1950s the organization developed and produced the first Mach II operational aircraft, the F-104 Starfighter.

High-Altitude Reconnaissance Jets

The famed U-2 high-altitude reconnaissance aircraft was developed in the Skunk Works in the mid-1950s and remains the world's highest flying, single-engine, manned aircraft. The modern U-2S and ER-2 derivatives are in worldwide service today with the U.S. Air Force and NASA.

In the 1960s, working in total secrecy, the Skunk Works produced the SR-71 Blackbird, a twin-engine Mach III reconnaissance aircraft that for more than two decades has held a series of world records for speed and altitude. After being retired from Air Force Service for five years, the SR-71 is scheduled to return to USAF duties in the summer of 1995. Early in the year, the Skunk Works received a contract to refurbish three Blackbirds that had been in storage and prepare them for redelivery to the Air Force. SR-71s also are flown by NASA for high-altitude research missions.

First Operational Stealth Aircraft

Perhaps the best-known Skunk Works development of recent years is the F-117A Stealth Fighter, a standout performer in raids against heavily defended targets during the 1991 Persian Gulf War. The world's first operational stealth aircraft, the F-117A evolved in secrecy for more than a decade before the Air Force disclosed its existence in 1988. At present, the Skunk Works is proposing advanced new derivatives of the F-117 that can operate from Navy carriers at sea and also meet Air Force requirements for the early 21st century.

(over)

A number of exciting new programs are under development in the Skunk Works today. These include DarkStar, an unpiloted reconnaissance vehicle for the U.S. Department of Defense being developed with Boeing under a contract awarded in 1994. First test flight of the initial DarkStar prototype is scheduled for the fourth quarter of 1995. The project is part of the DoD's Tier III Minus program.

A large-scale wind tunnel model was completed at the Skunk Works in the spring of 1995 as part of the DoD's Joint Advanced Strike Technology (JAST) program to develop a family of tactical aircraft for future use by the Air Force, Navy and Marine Corps. The jet-powered model, 86 percent of the size of the proposed STOVL strike fighter, will undergo wind tunnel and tethered flight tests at the NASA Ames Research Center in California. This supersonic aircraft would have short takeoff and vertical landing capability and could eventually replace the Marine Corps' AV-8B Harrier and F-118 Hornet. This is part of a competition managed by the Advanced Research Projects Agency (ARPA).

In March, 1995 a team led by the Skunk Works was selected by NASA for the first phase of a competition to design a new type of reusable space launch vehicle. The competition will lead to development and flight testing of a technology demonstrator vehicle called X-33. The Skunk Works' entry into the competition will employ proven lifting body technology and be powered by a linear aerospike rocket engine. Designed to deliver commercial or military payloads to low Earth orbit at a fraction of the current costs, the launch vehicle would take off vertically and climb to orbit with a single stage, having no need to drop any booster rockets or fuel tanks in flight. After its mission it would glide to a landing on a conventional runway.

How the Skunk Works Got its Name

When Kelly Johnson brought together a handpicked team of Lockheed engineers and manufacturing people at Burbank in the wartime year of 1943, each team member was cautioned that design and production of the new Shooting Star jet fighter must be carried out in strict secrecy. No one was to discuss the project outside the small organization, and team members were even warned to be careful how they answered the telephones.

A team engineer named Irven Culver was a fan of Al Capp's newspaper comic strip, "Li'l Abner," in which there was a running joke about a mysterious place deep in the forest called the "Skonk Works." There, a strong beverage was brewed from skunks, old shoes and other strange ingredients. One day Culver's phone rang and he answered it by saying "Skonk Works, inside man Culver speaking," Fellow employees quickly adopted the name for their mysterious part of Lockheed, where the new jet fighter program was brewing. "Skonk Works" became "Skunk Works." The once informal nickname is now the registered trademark of the company known as Lockheed Martin Skunk Works.

# # #

June 1995

The Skunk Works Team

LOCKHEED MARTIN

AlliedSignal AEROSPACE

ROHR

Rockwell Aerospace Rocketdyne

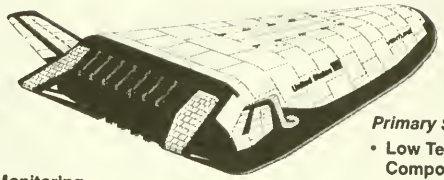
NASA

Lockheed Martin Skunk Works

Technology Requirements
Single Stage to Orbit Launch Vehicle

Propulsion
- Altitude Compensating Linear Aerospike Engine
- Low Risk Gas Generator Cycle
- Robust Hydrostatic Bearing Turbopumps
- Differential Thrust Vector Control
- Integrated Engine / Vehicle Structure

Reusable Cryogenic Tank
- Lighter Materials
- Semi Conformal Tanks
- Reusable Cryogenic Insulation



Systems/Avionics
- Single Non Toxic LH_2 Fuel
- Electric Controls
- Autonomous Operations
- Integrated Vehicle Health Monitoring
- Rapid Mission Planning

Primary Structure
- Low Temperature Graphite Composites

Thermal Protection System
- Ox Resistant Carbon Nose Cap & Edges
- Robust Light Weight Metallic Lower TPS
- Robust Upper Surface Fiberous TPS

Lifting Body Aero Shell
- Lifting Body Aerodynamics
- Highly Integrated Structure

LOCKHEED MARTIN AlliedSignal AEROSPACE ROHR Rockwell Aerospace Rocketdyne NASA

Mr. SENSENBRENNER. Thank you, Mr. Gordon, for some really excellent testimony.

Finally, batting cleanup is Dr. Ray Williamson, late of OTA, and perhaps of the late OTA, and now with George Washington University.

Dr. Williamson?

STATEMENT OF DR. RAY WILLIAMSON, SENIOR RESEARCH SCIENTIST, SPACE POLICY INSTITUTE, THE GEORGE WASHINGTON UNIVERSITY

Dr. WILLIAMSON. Thank you, Mr. Chairman.

I appreciate the opportunity to testify today. One of my last tasks while at the Office of Technology Assessment was to take part in drafting two reports on space transportation for this committee. They were directed by Christopher Waychoff.

With your permission, I would like to include in the record the summary from this report.

Mr. SENSENBRENNER. Without objection.

[The report referred to follows:]

THE NATIONAL SPACE TRANSPORTATION POLICY

Issues for Congress

Office of
Technology
Assessment

Congress
of the
United States

Summary

As the year 2001 approaches, visions of annular space stations and tourist flights to the Moon remain science fiction. With fewer than six years until the new millennium, the U.S. space transportation technology and industrial base is faced with a number of challenges, and some opportunities.[1]

The federal government has been the primary customer for space transportation services since the early days of rocketry. Recent efforts to reduce the federal budget deficit, cut the national debt, and shift development responsibilities to the private sector, however, have limited government funding for new space transportation technologies and missions. Similarly, the end of the Cold War has led to a reexamination of defense and national security spending on space missions and long-range ballistic missiles.

Meanwhile, European, Russian, and Chinese launch providers have captured more than 60 percent of the global commercial launch market for medium launch vehicles (MLVs). At the same time, entrepreneurs in the telecommunication, navigational, and remote sensing satellite industries predict an increasing need for launch services to establish and maintain large constellations of new satellites.

[1] Space transportation in this report refers to vehicles able to carry payloads or passengers to orbit. Space transportation systems may be expendable launch vehicles (ELVs), partially or fully reusable launch vehicles (RLVs), and long-range ballistic missiles. Currently, the U.S. Space Shuttle is the world's only operational RLV. This report does not address suborbital launch systems or transportation systems designed primarily to move payload or passengers between or beyond Earth orbits.

To address these challenges and opportunities, on August 5, 1994, the White House announced the National Space Transportation Policy (NSTP), developed by the National Science and Technology Council and approved by President Clinton.[2] The Clinton Administration's four fundamental objectives for the NSTP were to establish new national policy regarding:

1. federal space transportation spending, consistent with current budget constraints and the opportunities presented by emerging technologies;
2. federal agencies' use of foreign launch systems and components;
3. federal agencies' use of excess ballistic missile assets for space launch, to prevent adverse impacts on the U.S. commercial space launch industry; and
4. an expanded private sector role in the federal space transportation research and development (R&D) decisionmaking process.[3]

This report examines the new policy and the implementation plans of the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the Departments of Transportation (DOT) and Commerce (DOC) in the context of these four fundamental objectives. The report raises issues for Congress to consider as it debates the funding, oversight, and legislative requirements of the new space transportation policy. General findings, issues for Congress, and critical decision points identified in the report are summarized below. The main body of the report provides background on the fundamental objectives and examines each issue for Congress in detail.

GENERAL FINDINGS

Lack of Consensus on U.S. Space Policy Goals

The U.S. space transportation technology and industrial base is in a period of tumult and uncertainty brought about by the end of the Cold War, a constrained fiscal environment, and a pending shift in responsibilities from the public to the private sector. Even more than ordinary times, such a period demands clear intermediate and long-term goals, strong Presidential leadership, and the formation of a national consensus among the executive branch, Congress, industry, and the public.

The NSTP states that "assuring reliable and affordable access to space through U.S. space transportation capabilities is a fundamental goal of the U.S. space program."[4] Most observers agree that reducing costs and improving reliability are important objectives for the U.S. space program. Reliable, affordable access to space is a necessary part of the nation's infrastructure for achieving broader space goals.

The policy implies that lowering the cost of access to space will allow the United States to do whatever it wants in space. It may be difficult to achieve lower launch costs, however, without a clearly articulated, long-term plan supported by adequate funding, especially when the government is asking industry to make significant investments in ambitious new space transportation development programs. Indeed, the Office of Technology Assessment (OTA) previously noted that "until the nation chooses *what* it wants to accomplish in space, and what the U.S. taxpayer is

[2] Presidential Decision Directive NSTC-4. Most, if not all, the text of this internal policy was released publicly in The White House, Office of Science and Technology Policy, "National Space Transportation Policy," Fact Sheet, Washington, DC, Aug. 5, 1994. See appendix for complete text.

[3] The White House, Office of Science and Technology Policy, "Statement on National Space Transportation Policy," Washington, DC, Aug. 5, 1994. See appendix for complete text.

[4] The White House Office, Office of Science and Technology Policy, op. cit., footnote 2, Intro.

willing to pay for, neither the *type* nor number of necessary launchers and facilities can be estimated with accuracy."[5]

Establishing a national consensus first requires a clear delineation of specific national space goals by the Administration and its implementing departments and agencies. Then the Administration must cultivate congressional and public support for these goals, and convince industry that pursuing and achieving these goals would serve its interests.

The Administration has outlined some broad national space goals, such as achieving the International Space Station. It has not made clear, however, how specific goals relate to each other. It has not issued, for example, an overall space policy to replace the 1989 space policy of the Bush Administration. Without a clear articulation of space policy and how it relates to the broader national agenda, it may be difficult for both industry and government to pursue space transportation goals with vigor.

As the experience of the last decade has shown, even if the Administration were to delineate clear and specific national space goals, industry officials might still be reluctant to commit corporate resources to new space transportation ventures without strong congressional support. This support, in turn, depends on the ability of Members of Congress to bridge jurisdictional divisions and reach a consensus on how to buttress national space goals.

Living Within Severe Budget Constraints

Fiscal constraints imposed by the budget deficit, the federal debt, competition from other programs, and a desire to reduce government spending have forced DOD and NASA to cut back on space transportation programs, and to attempt to fund more creatively those programs that remain (e.g., through public-private partnerships). Both DOD and NASA state that they can meet their current space goals, but many government and industry officials are skeptical. These officials point out the previous commitments to new space transportation systems that failed to produce operational vehicles despite less severe budget constraints (e.g., the National Launch System, the Advanced Launch System, the Air Force Space Lifter, the Shuttle C, the Shuttle II, and the National Aerospace Plane). The U.S. government could afford to fund fully new space transportation systems, but it has currently placed its spending priorities elsewhere. In the absence of more government spending, the government and industry will have to sustain a commitment to new ways of doing business if the challenges and opportunities confronting U.S. space transportation are to be met.

Government Demand Dominates the Space Transportation Market

Since the advent of the space age, the U.S. government has played a large and critical role in shaping the domestic space transportation technology and industrial base. The U.S. government created the base to build long-range ballistic missiles and place men on the Moon. The U.S. government and industry remain tightly entwined through R&D and procurement contracts, federal regulations, and the need for licenses, despite the rise of commercial space launch markets.

For at least the next decade, U.S. national security and civil demands for space transportation will continue to dominate the domestic industry. Even the most optimistic growth projections for the global commercial market do not forecast a significant shift away from the government without major changes in the marketplace (e.g., the development of a dramatically less-expensive space transportation system or the discovery of a commercially lucrative space activity). Moreover, some launch providers are reluctant to take the steps necessary to make their launch operations

[5] U.S. Congress, Office of Technology Assessment, *Access to Space: The Future of U.S. Space Transportation Systems*, OTA-ISC-415 (Washington, DC: U.S. Government Printing Office, April 1990), p. 21.

more commercially price-competitive, because the changes might conflict with government requirements or the government might demand similar savings.

Current Capabilities Can Meet National Security Requirements

The national security community currently requires a domestic capability to launch payloads into orbit. The existing fleet of launch vehicles can continue to meet this requirement for the foreseeable future. DOD's major new development program, the Evolved Expendable Launch Vehicle (EELV), is intended to reduce DOD space transportation costs, rather than ensure continued access to space. The EELV program attempts to maximize cost savings by replacing DOD's current stable of MLVs and heavy launch vehicles (HLVs), procured from several vendors, with a unified family of vehicles that share many common components and launch infrastructure and are built by a single launch provider. One consequence of this consolidation, however, is that a systemic failure in one vehicle might ground the entire family of vehicles along with its national security payloads.

Competing Interests Make Common Strategy Difficult

While all members of the space transportation technology and industrial base see a critical need to reduce the cost of space transportation, their differing interests make it difficult to agree on a common space transportation development strategy. National security space transportation decisions are largely driven by the need to reduce expensive HLV launch costs through the EELV program. NASA hopes to replace its aging Space Shuttle fleet with a new, low-cost reusable launch vehicle (RLV) in the high MLV class that would carry crews and cargo to and from the International Space Station. Most industry representatives want to focus development dollars on a smaller, reusable MLV, designed to recapture lost commercial market share worldwide, while small launch vehicle (SLV) producers and selected space scientists want to maintain U.S. leadership in SLVs.

Recognizing and balancing these competing interests is critical to the success of a truly national space policy. The NSTP and its implementation plans are careful to ensure that DOD and NASA needs are met, but are less diligent about meeting the needs of the private sector.

ISSUES FOR CONGRESS

The following section summarizes OTA's discussion of issues that may be of interest to Congress as it debates the future of U.S. space transportation. These issues are divided among the Clinton Administration's four fundamental objectives for the NSTP and correspond directly to the main body of the report.

Fundamental Objective #1: Space Transportation Funding and the Division of Responsibilities

The NSTP attempts to set government spending priorities for current and future space transportation systems by assigning specific roles and functions to designated departments and agencies. By placing DOD in charge of expendable launch vehicle (ELV) development and NASA in charge of continued Space Shuttle operation and RLV development, the Administration has taken a step toward reducing conflicts and redundancies within government space transportation development programs.

DOD currently spends roughly $1.6 billion (about 84 percent) of its $1.9-billion space transportation budget on its HLV program, the Titan IV, while NASA spends just over $4 billion per year on Space Shuttle modifications and operations. Each organization has individually initiated a set of programs to address the budgetary difficulties posed by these high costs (see table S-1).

An added dimension to the current effort to develop new space transportation systems is the role of the private sector—both in decisionmaking and

TABLE S-1: DOD and NASA Development Programs and Procurements

	Program	Description	Objective
DOD	Existing ELV upgrades	Upgrades to the current fleet of launch systems and supporting infrastructure.	Keep the existing ELV fleet flying safely and reliably. Achieve significant, short-term payoffs where possible.
	Evolved Expendable Launch Vehicle (EELV)	A new, single family of MLVs and HLVs based on an evolutionary redesign of one or more existing ELVs.	Lower overall cost of access to space for DOD, especially for heavy payloads, by using common subsystems, components, and infrastructure.
NASA	Space Shuttle upgrades	System improvements and replacement of aging subsystems and components.	Keep the Space Shuttle flying safely and reliably.
	Med-Lite	A launch system with capacity falling between existing SLVs and MLVs.	Acquire a less expensive vehicle to serve future planetary exploration mission requirements
	DC-XA	Upgrades to the DC-X (a vertical-takeoff/vertical-landing, sub-scale, fully reusable, single-stage-to-orbit technology demonstrator) with more advanced components	Demonstrate system operability by testing new components and the integrated system in a realistic flight environment.
	X-33	A sub-scale advanced technology demonstrator that will be, at a minimum, an autonomous, suborbital, experimental, single-stage-to-orbit RLV.	By 2000, prove the concept of a fully reusable single-stage-to-orbit space transportation system in the high MLV class by demonstrating key technology, operations, and reliability in an integrated flight vehicle. Encourage private investment in a commercial follow-on RLV by reducing the technical risks of SSTO.
	X-34	A partially reusable demonstration vehicle for small payloads.	Investigate technologies that may be incorporated into future RLVs. Demonstrate streamlined management of joint industry-government development effort. Address commercial and U.S. government need for an inexpensive SLV
	Supporting RLV technology demonstration	Development and validation of propulsion, structural, and operations technologies.	Progressively integrate and flight-demonstrate these technologies on three experimental test vehicles (DC-XA, X-33, and X-34) in order to 1) mature technologies required for a next-generation launch system, 2) demonstrate the capability to achieve low development and operational costs, and rapid launch turnarounds, and 3) reduce technical risk to encourage private investment in the commercial development and operation of next-generation systems.

SOURCE Office of Technology Assessment, 1995

financing. This has important implications on the nature of space transportation development programs and raises an entirely new set of considerations that must be taken into account when evaluating development programs proposed by both DOD and NASA.

ISSUE 1a: *Divided responsibility and interagency coordination*

The NSTP divides the government's primary responsibilities for space transportation between DOD and NASA. If existing space transportation assets and those under development are to be managed in a manner conducive to all interests, this division of responsibility will increase the need for both organizations to coordinate with one another, as well as with the private sector.

That DOD and NASA will adequately account for the interests of all parties is not a certainty, especially as funds available for space transportation diminish. Conflicts over how to approach the development of new space transportation systems will undoubtedly arise. At present, it appears that resolution of these conflicts will be achieved via negotiations between DOD and NASA on a case-by-case basis, possibly with some mediation by a third party within the executive branch. Such negotiations may succeed in satisfying both DOD and NASA, but could fail to account for the interests of all relevant parties, especially those in the private sector.

Such negotiations could also lead to programmatic redundancies. In the absence of central authority or leadership, DOD and NASA may discount potential redundancies and simply continue to promote those projects that best address their own organizational requirements. As a result, hard space transportation policy choices may go unmade.

Many analysts and policymakers have proposed a central authority as a way to better account for all interests and avoid programmatic redundancies. In the Bush Administration, for example, Vice President Quayle was given considerable authority over space transportation policy. It is not clear, however, that the imposition of a central authority has remedied these problems in the past, or that it will necessarily do so in the future. Given the considerable bureaucratic and political weight of DOD and NASA, competing organizational interests could potentially override the wishes of a central authority. Furthermore, existing legal and organizational obstacles may prevent the level of interagency and private sector coordination sought by a central authority.

The recent controversy between DOD and NASA over NASA's Med-Lite procurement may be emblematic of this latter problem. This controversy illustrates how interagency coordination can be precluded by current law, divergent interpretations of that law, and competing organizational interests. Therefore, although the NSTP calls on DOD and NASA to "combine their [ELV] requirements into single procurements when such procurements would result in cost savings or are otherwise advantageous to the government," achieving this level of interagency coordination may prove extremely difficult.

ISSUE 1b: *Potential conflicts and redundancies*

DOD and NASA have collectively proposed a sizable portfolio of new space transportation technology development programs. While this multitrack approach may reduce the overall risk of pursuing new space transportation systems, it may also lead to potential conflicts and redundancies and higher overall costs. For example, development of a commercially competitive EELV by DOD could undercut NASA's effort to commercialize a follow-on to the X-33 by reducing the incentive for private investors to fund a technically risky RLV.

If a low-cost RLV is developed, nonetheless, it may be difficult for the EELV program to achieve the long-term cost reduction targets set by DOD. At a minimum, the RLV will compete with the EELV for payloads, possibly attracting payloads away from the EELV. Were this to occur, it would reduce savings generated by the EELV program by offsetting or potentially outweighing any gains in production volume created by commonality within the EELV family.

As for NASA's dual-track RLV development strategy, the Agency believes that early X-34 test flights could positively affect X-33 development by steering it toward or away from certain technologies. Moreover, proponents note that the X-34 could generate significant benefits for the government, industry, and consumers of space-based services if its target of threefold cost reductions for launching small payloads are achieved.

Critics, however, have suggested canceling the X-34 program, arguing that it is geared toward developing an operational vehicle, not an experimental vehicle, and that its cancellation would not affect the technological success of the X-33 program.

There are other potential conflicts and redundancies. In particular, DOD officials are concerned that the Med-Lite vehicle might eventually compete with the EELV for medium payloads, thereby threatening the ability of the EELV program to achieve maximum launch cost reductions for DOD. In addition, NASA has proposed to phase in any newly developed RLV follow-on to the X-33 between 2005 and 2012 while continuing to fly the Space Shuttle in support of the International Space Station.

ISSUE 1c: *HLVs drive the EELV program*

DOD currently spends $1.6 billion of its $1.9-billion space transportation budget on its HLV program. Therefore, DOD has geared the EELV program toward achieving significant HLV cost reductions. DOD's focus on HLV cost reductions, however, ignores the need of U.S. launch providers to develop a commercially competitive launch vehicle in the hotly contested MLV market. While the EELV program may reduce MLV costs by as much as 10 percent, such a cost reduction would probably not help the EELV manufacturer recapture a significant portion of the global market for launch services. And without an increased share of the available market, DOD will receive little, if any, additional price reductions generated by larger production volumes.

On the other hand, the European Space Agency's (ESA's) development of the heavy-lift Ariane 5 suggests that significant HLV cost reductions may be commercially attractive. It is unlikely, however, that the heavy-lift EELV will be inexpensive enough to compete with the Ariane 5, even if it achieves a 40 percent cost reduction over the Titan IV.

ISSUE 1d: *RLV development*

NASA has pointed to its RLV development strategy as one example of its "new way of doing business." Outside of NASA, however, some have expressed concern over NASA's proposed RLV development strategy. In particular, industry officials are concerned that property and data rights issues, as well as the uncertainty surrounding the distribution of core RLV technology development funds, may slow or prevent RLV commercialization.

Other analysts and policymakers believe the X-33 program should be structured differently. Some critics have argued that the X-33 is being designed in the shadow cast by future requirements for the International Space Station, and that it would be better if NASA opted to fund fully an X-33 program that focuses solely on demonstrating single-stage-to-orbit (SSTO) technology. NASA officials believe the X-33 does focus on demonstrating SSTO technology, but contend that industry investment is appropriate because the successful development of a low-cost, commercial RLV will significantly improve the competitiveness of the U.S. space transportation industry, and because government space budgets are declining.

Others critics of the X-33 program structure have suggested a competitive fly-off among competing X-33 concepts, a strategy in which NASA has expressed some interest. Proponents of a fly-off believe that it would decrease the possibility of choosing the "wrong" technology and increase the likelihood of retaining competition in the domestic launch vehicle industry. Critics note, however, that a fly-off strategy would require larger near-term budgets than currently planned.

Another concern surrounding RLV development has been the role of DOD payloads and

whether or not they will be used during the early testing of a commercial RLV. NASA and its commercial partners will need a sufficient number of payloads to both prove the reliability of RLV technology and attract potential investors. DOD officials, however, do not wish to repeat their negative experiences with the Space Shuttle and are, therefore, hesitant to contribute DOD payloads to the RLV until it is proven. Unless NASA and its industry partners can entice other payloads to fly aboard an RLV, DOD's reluctance could potentially drive up the price of launching payloads on the RLV.

ISSUE 1e: *SSTO?*

SSTO development entails significant technical risks. NASA has proposed a phased SSTO technology maturation program that periodically pauses along the way to determine the prudence of continuing. In the event the pursuit of SSTO is terminated at any point, NASA suggests that other RLV concepts (e.g., two-stages-to-orbit or TSTO systems) can then be considered and that new RLV efforts could possibly draw on past SSTO technology development efforts.

Some analysts and policymakers have taken issue with this approach, arguing that it grants too much upfront attention to the SSTO concept. They note that pursuing another RLV concept such as TSTO after investing significant resources in SSTO risks a suboptimal result that does not achieve the desired level of cost reductions.

Also, there has been some concern that NASA has not adequately defined its criteria for judging the success of the X-33 program. NASA, in conjunction with the Office of Science and Technology Policy and the Office of Management and Budget, has established criteria to support decisions in 1996 and 2000. Nevertheless, some analysts and policymakers are concerned that these criteria are insufficient and suggest that NASA provide Congress with a set of specific intermediate criteria for evaluating the success of the X-33 program on an annual basis. Such a requirement may, however, slow the development process.

Finally, although NASA has claimed that it must pursue block upgrades to the Space Shuttle if the government or industry decides in 2000 to forgo development of a commercial RLV follow-on to the X-33, there are other alternatives. For example, NASA could decide to extend SSTO development efforts, initiate TSTO development efforts, support development of a commercial TSTO, pursue block upgrades to the Space Shuttle, commission a new space transportation study, or reconsider alternative options already examined in past studies. Which alternative NASA chooses in coordination with its industry partners will depend on the progress made during the X-33 program, as well as the commercial prospects of an RLV.

ISSUE 1f: *Space Shuttle—beyond 2000*

As noted, NASA may decide in 2000 to pursue block upgrades to the Space Shuttle in order to ensure safe operations until 2020. Discussions with both NASA and industry officials reveal, however, that little planning for this possibility and little investigation into whether or not the industrial base will be able to support these upgrades are currently being done by NASA.

In its implementation plan, NASA has proposed replacing the existing solid rocket boosters (SRBs) with Liquid Fly Back Boosters (LFBBs) between 2007 and 2010. NASA claims that LFBBs would increase Shuttle safety, payload performance, and launch probability, and would also reduce annual Shuttle operating costs compared with SRBs. The implementation plan does not, however, outline any contingencies to address the significant impact that replacing SRBs with LFBBs might have on the solid rocket motor industry and the nation's continued ability to produce long-range ballistic missiles.

Finally, there remains the prospect of another Space Shuttle accident that results in the loss of an

Orbiter. Such a loss would have major repercussions for both the Space Shuttle and X-33 programs.

Fundamental Objective #2: U.S. Use of Foreign Launch Systems and Components

The NSTP encourages federal agencies to take advantage of foreign technologies in U.S. space transportation systems. It also limits the flight of U.S. government payloads to U.S. space transportation systems, in effect removing U.S. government payloads from the available international marketplace for launch services. In this, it follows past policy. In addition, the policy allows the launch of government payloads on foreign launch vehicles if they are made available on a no-exchange-of-funds basis and if they support cooperative scientific programs.

ISSUE 2a: *The use of foreign launch technology*

The use of foreign technologies in U.S. space transportation systems may improve the efficiencies of U.S. launch systems, assist U.S. access to space, and improve U.S. competitiveness in the international space transportation market. With the important exception of the Space Shuttle and its main engines, the United States has done relatively little launch system R&D since the 1960s. The use of foreign technologies in U.S. space transportation systems could reduce the amount of R&D now required of U.S. firms in efforts to improve the performance and reduce the costs of U.S. systems. Russian launch vehicles and related systems (particularly propulsion) have significant potential for commercial use. Russian hardware and space transportation skills can fill important gaps in U.S. capabilities. The United States might benefit from European space transportation technologies as well.

On the other hand, U.S. national security interests demand that the United States maintain a viable national launch capability and technology base. The use of foreign technologies might reduce the incentives for maintaining the domestic R&D that underlies that technology base.

The simple purchase of either vehicles or launch services appears to be less attractive than joint ventures, co-production of vehicles and/or systems, and analogous business arrangements, as ways of harmonizing these differing interests. For example, Aerojet and Pratt and Whitney, both U.S. manufacturers of liquid-fueled engines, are exploring ways in which to capitalize on the use of Russian liquid-fueled engines in U.S. vehicles.[6] U.S. launch operations experts have expressed interest in Russian and European methods to reduce operations costs. In its implementation plan, DOD has expressed openness to the use of foreign technologies in U.S. launch vehicles, but only under conditions that would protect the supply of critical components should foreign sources become unavailable. Each proposed technology insertion would be judged on a case-by-case basis.

Methods to protect component supply, such as stockpiling critical components or duplicating production lines in the United States would likely result in higher costs to the government, but might ensure that the United States will be able to fulfill its space-related national security needs in times of crisis. Officials of Arianespace have offered to sell the Ariane 5, or license rights to build it, to service U.S. HLV needs. Such an arrangement could substantially reduce the costs of building and operating a U.S. HLV.[7] However, building a vehicle under license might inhibit the development of new U.S. technology that could be used to improve the U.S. MLV fleet.

Experts disagree over the extent to which cooperation with the Russian government and industry on space projects would affect U.S. competitive-

[6] Michael A. Dornheim, "Aerojet Imports Trud NK-33 Rocket Engine," *Aviation Week and Space Technology*, Oct. 25, 1993, p. 29; and Jeffrey M. Lenorovitz, "Pratt Signs Accord with NPO Energomash," *Aviation Week and Space Technology*, Nov. 2, 1992, pp. 25-26.

[7] Ben Ionatta and Cheri Privor, "Arianespace's EELV Proposal Finds Little Favor," *Space News*, Apr. 10, 1995, p. 3.

ness and the retention of U.S. jobs. Some industry officials, for example, express concern that the United States could lose employment in the launch services industry if Russian technology were used extensively in U.S. launch systems. Others have argued that skillful incorporation of Russian technologies in U.S. systems could save taxpayer dollars in publicly funded programs like the International Space Station and boost U.S. international competitiveness in commercial programs. Greater competitiveness might generate new jobs in space transportation and space-related fields, partially or fully offsetting job losses due to the use of foreign technology.

Second-, third-, and fourth-tier launch system equipment suppliers appear to be most vulnerable to the extensive use of Russian technology in U.S. launch systems, especially those that now supply subsystems and parts for U.S. propulsion systems. Loss of critical skills in the lower tiers of the space transportation industrial base may, in some instances, adversely affect the nation's ability to maintain assured domestic access to space and reconstitute production of long-range ballistic missiles. Nevertheless, reducing the cost of access to space may well lead to more aerospace jobs as a whole.

Some observers worry that given the precarious state of the Russian economy and government, Russian equipment suppliers may not be able to sustain their ability to produce space goods and services.[8] Russian firms, recently privatized and undergoing massive restructuring, have experienced difficulties in moving to a demand-driven, market-oriented economy. Concern over the future ability of Russian firms to perform could be eased, in part, if Russian firms successfully demonstrate that they can produce goods and services on time and within the terms of cooperative contracts with the U.S. government and industry. The existing cooperative activities between NASA and the Russian Space Agency, especially with regard to construction and operation of the International Space Station, will provide considerable insight into the long-term viability of the Russian space transportation industry.[9]

The NSTP also allows the use of foreign launch systems to carry U.S. instruments and spacecraft on a no-exchange-of-funds basis when supporting cooperative programs with other countries. Examples of such cooperative use of non-U.S. launchers include the shipment of U.S. equipment to the Russian Mir space station aboard a Russian Spektr spacecraft launched on a Russian Proton launch vehicle in May 1995, and the earlier launch of the TOPEX/Poseidon spacecraft on an Ariane 4 in 1992. Such use can sharply reduce U.S. costs for science programs and may facilitate some projects that might otherwise not be flown, but could deprive U.S. launch providers of a few launch opportunities. The launching country gains by receiving access to data generated by the U.S.-built, or jointly built, instrument or spacecraft.

ISSUE 2b: *International trade in launch services*

In keeping with broader U.S. international trade principles, the NSTP seeks to achieve free and fair trade in launch services. However, as a result of the close connections between defense and launch system technologies, and the desire to achieve or retain autonomy in launch services, all spacefaring nations subsidize their launch services industry to some extent. Because the economic structure of each country is different, it is difficult to determine the true extent of the subsidy each extends to its launch industry. In addition, each spacefaring country generally reserves government payloads for its own launch systems. For example, in keeping with past U.S. policies, the NSTP requires that U.S. government payloads fly

[8] Judyth L. Twigg, "The Russian Space Program: What Lies Ahead?" *Space Policy* 10(1):19-31, 1994.

[9] U.S. Congress, Office of Technology Assessment, *U.S.-Russian Cooperation in Space*, OTA-ISS-618 (Washington, DC: U.S. Government Printing Office, April 1995).

on U.S. space transportation systems, except for well-defined cooperative programs.

Trade agreements with China and Russia, which are intended to manage the international market for launch services and reduce the impact of low Chinese and Russian prices on U.S. launch service companies, may also reduce international competition and raise the overall price of launch services. The United States first faced competition from non-U.S. launch service entities after ESA developed the Ariane launch system in the late 1970s. Specifically designed to carry payloads to geosynchronous Earth orbit (GEO), and marketed by the European corporation Arianespace, the Ariane system was designed and built on the premise that it would capture a significant share of the available world market in commercial payload launch services. Since the loss of the Space Shuttle *Challenger* in January 1986, Arianespace has garnered a dominant share of the international commercial payload market.[10]

During the late 1980s, China and Russia (then the Soviet Union) began to offer launch services on the international market, increasing the competitive pressure on the U.S. commercial launch services industry. Faced with growing competition in launch services, increasing concern that launch systems built in non-market economies would unfairly compete with U.S. launch systems, and pressure from U.S. satellite manufacturers to allow the launch of U.S.-built satellites on Chinese and Russian launch systems, the United States sought and obtained launch service agreements with China and Russia.

In addition to setting limits on the total number of Chinese and Russian launches within a specified period, the agreements attempt to establish rules by which the market will operate. The United States is able to exert influence over trade in launch services because it sells more satellites on the international market than any other country. Russia and China have signed trade agreements because the United States could severely restrict the international sale of U.S.-manufactured satellites launched on other countries' vehicles. The Office of the U.S. Trade Representative (USTR) is the U.S. agent in negotiating these agreements.

U.S. satellite manufacturers have begun to pressure the USTR to relax or do away with the existing restrictions on the number of Russian commercial launches allowed between now and the end of the century. They have been joined by U.S. partners of Russian launch companies, which would profit from relaxed restrictions. Existing and planned partnerships between U.S. and Russian companies are likely to complicate U.S. considerations of these agreements, making it much more difficult to assess overall benefits and drawbacks of changes in the agreements.[11] Relaxation of the U.S.-Russia agreement would make the launch services market more competitive. It might also undercut the ability of U.S. launch service providers to compete and indirectly raise the costs of space transportation services to the federal government.

Arianespace, which now commands the largest share of the commercial launch services market, may be more affected by a relaxation of the U.S.-Russia launch services agreement than U.S. firms. Although a relaxation of the agreement would increase the competitive pressures on U.S. launch companies not now associated with Russian companies (such as McDonnell Douglas, which markets the Delta MLV, and Orbital Sciences, which markets the Pegasus and Taurus SLVs), those companies launch payloads for the U.S. government and therefore would retain a strong core market for launch services. Lockheed Martin, which markets the Atlas ELV, also markets the Russian Proton

[10] Prior to the loss of *Challenger*, NASA actively marketed commercial launch services on the government-owned and -operated Space Shuttle. In August 1986, President Reagan issued a policy directive limiting the use of the Shuttle to payloads that required the unique capabilities of the Shuttle.

[11] Craig Covault, "Russian Proton Challenges Ariane," *Aviation Week and Space Technology*, Apr. 24, 1995, pp. 40-43.

through LKE International. Lockheed Martin intends to use the two vehicles to back each other up, should one be temporarily removed from service to correct a system failure.

ISSUE 2c: *Technology transfer and foreign policy objectives*

Cooperative ventures risk transferring domestic technologies that could be used to strengthen a competitor's position in the international aerospace market and to assist belligerent countries in developing the means of delivering weapons of mass destruction (nuclear, chemical, and biological weapons). Experts disagree over how effective means to prevent such transfer can really be, but present policy clearly moves toward loosening trade restrictions. For example, many items having to do with satellites and satellite technology have been moved from the U.S. Munitions List onto the Commerce Control List, effectively making it easier to trade in those items. Further loosening of restrictions could result in improved U.S. trade in space transportation technologies. On the other hand, the United States must also remain sensitive to the potential proliferation of missile-related technologies.[12]

U.S. cooperative agreements with other countries must conform with related U.S. obligations and treaties, such as technology transfer policies and the Missile Technology Control Regime (MTCR), which was developed in 1987 to limit proliferation of long-range delivery systems capable of delivering weapons of mass destruction.

Admittance to the U.S. satellite market has become a tool in encouraging adherence by China, Russia, and Ukraine to the MTCR. Russia and Ukraine have agreed to join the MTCR. The Clinton Administration believes that helping the Russian civilian space program stay as healthy as possible and capable of retaining its experts will reduce global proliferation of missile technology. China has declined to join the MTCR, but has agreed to abide by its restrictions. However, the United States has raised several issues of noncompliance with Chinese officials. On October 4, 1994, the United States and China agreed to "work together to promote missile nonproliferation through a step-by-step approach to resolve differences over missile exports."[13] The United States could levy sanctions against the Chinese launch company, including prohibition of satellite launches, if the United States found that the entity was selling missile-related technology to a country that did not previously possess such technology.

Fundamental Objective #3: The Use of Excess Ballistic Missiles

The NSTP reserves use of excess ballistic missiles for government payloads only, and only when their use results in cost savings to the government over the use of commercial launch services. Excess ballistic missiles can be used by the government for engineering tests and suborbital flights, but orbital flights that might compete with private launch services must satisfy tough conditions before they are allowed.

Some 650 long-range ballistic missiles will be made available by U.S. adherence to the first Strategic Arms Reduction Talks treaty alone. These missiles, and others to be retired under other treaties, could be used to launch government and commercial satellites into orbit. Even if the missiles themselves are not used, parts of the missiles and the tooling for building those parts could be useful to industry.

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[12] U.S. Coogress, Office of Technology Assessment, *Export Controls and Nonproliferation Policy*, OTA-ISS-596 (Washington, DC: U.S. Government Printing Office, May 1994).

[13] U.S. Department of State, Office of the Spokesman, "Joint United States-People's Republic of China Statement on Missile Proliferation," Fact Sheet, Oct. 4, 1994.

ISSUE 3a: *Unfair competition or market creation?*

The Clinton Administration's policy continues the Bush Administration's policy of tightly restricting the use of excess long-range ballistic missiles. Some analysts argue that making these missiles more widely available for use as space launch systems would not only save much needed government resources, but could also demonstrate the viability of new markets for SLVs. Others argue, however, that although such a scheme might save the taxpayers money in the short term, it might also drive commercial SLV vendors from the market, leaving the U.S. industry with no SLV producers in the long term.

There is a lack of data on how much it would cost to convert surplus ballistic missiles for new payloads, how useful these missiles might be for more delicate payloads, and how SLV providers might maintain their ability to develop new systems should converted ballistic missiles be priced below current SLVs. Those questions must be answered before the debate on how to use excess ballistic missiles can be resolved.

ISSUE 3b: *Russian excess ballistic missiles*

In contrast to American policy regarding surplus missiles assets, former Soviet Union firms are promoting a number of converted intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles for an assortment of commercial duties. Two already on the market are the Start-1 and the Rokot, derived from the SS-25 and SS-19 ICBMs, respectively.

Russia's use of its excess ballistic missiles as SLVs has not yet proven to be a viable commercial strategy. If Russia is successful in marketing its surplus ballistic missiles, however, U.S. SLV launch service providers will face international competition from Russian excess ballistic missiles, while the U.S. government will receive none of the benefits of selling its stockpiles.

Fundamental Objective #4: The Private Sector Role in Space Transportation Decisionmaking

The private sector is expected to play a crucial role in accomplishing many of the space transportation goals set forth in the NSTP and the supporting implementation plans. It is, for example, designated to be a source of: 1) significant funding in a fiscally constrained budget environment; 2) expertise to manage space launch activities more efficiently; and 3) innovative ideas and products in the design and development of future space transportation systems. Placing greater reliance on the private sector is in keeping with general trends that emphasize reducing government's responsibilities in areas in which the private sector might reasonably be expected to provide the desired goods and services.

But the private sector is not a monolithic entity with a single coherent view of space transportation needs or the goals outlined in the NSTP. While the principal prime contractors for space transportation are in general agreement on many aspects of the Clinton Administration's space transportation policy, they have different views about the implications of particular elements of policy. Additionally, some subtier firms are skeptical about the potential for the government to achieve the goals of the NSTP.

The willingness and, indeed, the ability of private sector firms to fulfill the roles suggested in the national space transportation planning documents depend in many instances on factors that possess a great deal of uncertainty and are difficult to estimate accurately (e.g., the size and character of the future commercial space transportation market) and that are highly dependent on actions by the government (e.g., the nature of any government-industry partnership). These facts raise several issues that Congress might wish to consider in evaluating the role that the private sector plays in implementing the Administration's policy.

ISSUE 4a: *Will the estimated market support policy goals?*

In the absence of a major increase in the government's space transportation budget, private sector investment is viewed as essential for the development and production of an RLV follow-on to the X-33 possessing the characteristics desired by NASA. But any private sector investment depends on the potential for sufficient return on that investment to make it attractive. The assessment of the size, character, availability, and relationship (potential overlap) of future space transportation markets is therefore critical to industry's attitude toward new launch vehicle development programs and government cost-sharing arrangements.

The current industry assessment of the space transportation market appears to be that the potential market for commercial payloads in the MLV class is by itself insufficient to entice enough private sector investment to build a future RLV capable of meeting NASA's needs.

Current analysis indicates that the government is likely to continue to be the largest single market for U.S. space transportation for at least the next 10 to 15 years. Expansion of the commercial market in areas such as communications and earth observation is probable, but the size and rapidity of such expansion is uncertain. A number of potential new markets, such as space manufacturing and tourism, are on the horizon, but the size and speed of development of these markets are uncertain. This uncertainty about future markets inhibits private sector investment.

Industry analysis indicates that the potential commercial market for small payloads may be sufficient to attract enough private sector investment to develop vehicles to meet both commercial and government needs for small payloads. The willingness of firms to invest in the X-34 program supports this conclusion.

U.S. industry sees little commercial need for heavy lift and views this as principally a government market. The private sector is unlikely to put much of its own funds in this area without strong government support. Some observers note, however, that Arianespace plans to replace its medium-lift Ariane 4 with the heavy-lift Ariane 5.

Such assessments imply that if the government desires an RLV replacement for the Space Shuttle, it will have to provide a significant amount of the funding—either through a direct development and procurement process or through some form of guaranteed business.

ISSUE 4b: *The nature of the government-industry space transportation partnership*

The NSTP and implementation plans stress the need for closer government-industry cooperation—what NASA terms a partnership. Government planners believe that a more important role for industry in decisionmaking is essential if industry is going to be asked to help finance much of the production of a future medium-to-heavy-lift RLV. There are, however, a number of questions about the nature of any new government-industry relationship and the possible implications of closer ties between the government and any particular firm.

There appear to be a number of advantages to closer cooperation between government and industry. One is a potentially more efficient and less costly management structure. Another benefit is more effective use of the nation's public and private sector space transportation industry's technical expertise and facilities. But closer cooperation raises serious questions about who decides what research topics to pursue, which efforts will be funded, who will own the technical data rights resulting from this partnership, and how these rights might be transferred if such transfer appears to benefit the government. These questions and many others will have to be addressed if a partnership is to be successful.

Each government organization appears to have different expectations for the government-industry relationship. The designated advocates of increased commercial participation are the DOT and DOC, but with little money and small staffs, these two Departments are likely to play a limited role. NASA needs private sector investment to build a new RLV. It is, therefore, interested in policies

that will provide support for industry, as well as incentives for industry to invest. It has streamlined its program management, changed funding rules, and made its research staff available to industry.

DOD, in contrast to NASA, does not have the same perceived need for a new space launch vehicle to perform its missions. Its current capabilities are more costly and less flexible than desired, but they perform well enough to meet the Department's fundamental mission requirements. DOD therefore appears less concerned about developing a close partnership with industry than is NASA.

ISSUE 4c: *Risk management—striking the proper balance*

Uncertainties about the future space transportation markets increase the need for private sector firms to protect any investment against losses. With estimates on the cost of development and production of a future medium-to-heavy-lift RLV ranging from $6 billion to $20 billion, many in industry are supporting the concept of anchor tenancy (e.g., committing the federal government to purchase an agreed upon amount of launch services from commercial firms) as a means of encouraging industry to invest in RLV development and production. By providing a guaranteed market for a specific period, anchor tenancy would reduce investment risk for the private sector during the formation of a more robust commercial market. A recent example of a commercial anchor tenancy is McDonnell Douglas' agreement to develop a Delta III ELV in exchange for a commitment by Hughes Telecommunications and Space Co. to purchase 10 future launches.

There are a number of issues that must be addressed. One is that a program based on anchor tenancy might be considered a "lease-purchase" arrangement. This could make the arrangement problematic because current government accounting rules require that such an arrangement be recorded in the budget as if the government purchases the assets outright. The discounted value of the expected costs of space launch services would be recorded as budget authority when the contract was signed. Outlays would be recorded (scored) in proportion to the construction activity on the launchers, as if the government were building the system.

Other observers argue that there is a need for new thinking in anchor tenancy, particularly when the government is slated to be less involved in the development of goods and services that might come from the private sector. They argue that anchor tenancy might be successfully used if the situation is one in which there is little technological risk, the contractor is taking the risk of performance, the contractor is financing the project, and the contractor has design control. Competitive bidding to help establish the market assessment of risk is also important.

Several industry representatives have argued that the basis for an anchor tenancy arrangement needs to be established by April 1996, when industry must begin to commit significant funds toward the development of the X-33 technology demonstrator. Without this commitment, industry may still participate in the X-33 program, but will probably reduce its share of the investment.

Industry also argues that termination liability (e.g., requiring the government to compensate industry should the government cancel a launch contract for its own convenience) is essential for reducing the risk to the private sector of entering into a long-term launch service agreement with the government. Skeptics have argued that such arrangements amount to providing a "risk-free" environment for U.S. business. Still, termination liability usually does not provide for loss of future revenue, only for money already spent. Thus firms continue to risk the loss of future returns on the money invested and bear the opportunity cost of not having invested the money elsewhere, even if compensation for funds already spent is guaranteed.

ISSUE 4d: *Infrastructure*

Many analysts argue that significant launch cost savings might be realized through changes in launch operations and infrastructure. Some have

suggested building new, more generic launch facilities. Many analysts indicate that important launch cost reductions are unlikely unless launch operations engineers and facility managers have a greater role in the design of future launch systems.[14] Efficient launch operations are key competitive advantages for both Arianespace and Russia. A future RLV may have a completely different launch infrastructure than that of ELVs.

Because of the importance of the impact of launch services and infrastructure to long-term government costs and commercial competitiveness, Congress may wish to pay particular attention to activities in these often overlooked areas. Questions of how future space transportation systems will operate and how such operations will save money in comparison with current operations might be key oversight issues.

ISSUE 4e: *Accommodating commercial needs*

Many in industry express concern over the extent to which development of new space transportation systems will be influenced by rigid government space launch and payload requirements rather than by accommodation of commercial space transportation competitiveness considerations. For example, although NASA has restructured its program management and made a number of procedural changes that can aid development, its program may still be best structured to produce an RLV that will serve the U.S. government's space transportation needs first—rather than producing a commercially viable vehicle that will also meet government needs.

Part of the problem is the NASA requirement to carry crews to and from the International Space Station. Another part of the problem is the inability to define what might be commercially viable. Some industry representatives have noted, for example, the need to design commercial vehicles to serve the GEO market. This might result in very different designs from those optimized for NASA's International Space Station mission. These issues will need to be resolved if the programs are to meet their objectives.

Additional Issues for Congress

Two important issues were not addressed by either the NSTP or its implementation plans, but warrant consideration by Congress. These are the preservation of long-range ballistic missile capabilities and the status of the lower tiers of the space transportation technology and industrial base.

ISSUE 5: *Preservation of long-range ballistic missile capabilities*

The U.S. Navy plans to procure the last long-range ballistic missile in the strategic nuclear arsenal in 2005. No plans currently exist to produce any additional missiles after that time. Without producing missiles, however, the United States' ability and capacity to design and produce long-range ballistic missiles will deteriorate unless significant efforts are made to preserve them.

Both the U.S. Air Force and the Navy have preservation programs underway, but they are limited to a small set of critical components. Solid rocket motor technology may be particularly threatened. At present, all U.S. long-range ballistic missiles use solid rocket motors. If both the EELV and RLV designs use only liquid-fueled engines, and if liquid-fueled boosters replace the Space Shuttle's solid rocket motors, the market for large solid rocket motors in the United States may all but disappear.

ISSUE 6: *The invisible lower industrial tiers*

Current policy focuses on the large prime contractors, but there is more to the U.S. space transportation industry than just those firms. Hundreds of smaller firms provide subsystems and components, to the extent that about 50 cents of every procurement dollar flows down to these lower tiers of the industry.

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[14] See U.S. Congress, Office of Technology Assessment, *Reducing Launch Operations Costs: New Technologies and Practices*, OTA-TM-ISC-28 (Washington, DC: U.S. Government Printing Office, September 1988).

OTA found that many of the lower-tier firms are pessimistic about their chances of survival. They believe that the government is not committed to the actual completion of new launch vehicles, and that research and development money will not find its way past the prime contractors.

Congress may wish to consider what the chances are that some of these lower-tier firms might be forced out of business, and what effect that is likely to have on the United States' ability to compete in the international market. If all the companies that produce a particular component or material critical to the space transportation industry go out of business because of lack of funds from the upper-tier firms, it could be very difficult and expensive to regain the capability to produce that component again.

CRITICAL DECISION POINTS

Each of the space transportation policy implementation plans was accompanied by an idealized timeline. While each department and agency was careful to say that the timelines were not set in stone, they do provide policymakers with some sense of the important decisions that await them and some of the hidden problems they may face in a few short years. Table S-2 lists some of the more critical decision points and their potential implications. Changes in political leadership, new space program goals, stretched out or terminated programs, unforeseen technical difficulties, and launch failures are just a few events that could dramatically alter the timing of these important decisions.

TABLE S-2: Critical Decision Points and Their Possible Implications

Date	Decision or event	Possible implications
1995	Corporate investment strategies for X-33 and X-34 development programs must be formulated.	Corporate evaluation that government programs are unlikely to transpire as advertised could result in inadequate corporate investment, creating a self-fulfilling prophesy
1996	Down-selection for Phase II of X-33 single-stage-to-orbit demonstration vehicle.	Industry participation in Phase II may require early government commitment to and legislative action on cost and risk sharing on the follow-on operational RLV. This is four years before NASA's specified 2000 decision on Space Shuttle upgrades (see below). Contract winner has an advantage for production of follow-on RLV, unless other companies invest in their own competitive vehicles or the contract winner fails to meet program performance and cost objectives.
1998	Down-selection to one EELV producer.	Contract winner will develop family of medium-to-heavy vehicles for DOD, perhaps consolidating U.S. ELV business to one firm. Med-Lite winner, however, may compete at lower payload range.
1999	X-34 RLV demonstration vehicle flight tests are completed.	A successful X-34 producer could potentially dominate the SLV market if significant per flight price reductions are achieved. U.S. government costs for SLVs drops. New markets may develop for LEO light satellites if X-34 producer drastically lowers per flight prices.
2000	Government decision required to pursue either a manned RLV variant or major block upgrades to the Space Shuttle	A premature decision to develop a manned RLV could result in a less-than-revolutionary vehicle. Spending on major upgrades to the Shuttle could indefinitely postpone RLV development to the detriment of government launch expenditures and U.S. competitiveness in the commercial launch market
2000+	Corporate decision to build a commercial RLV	Size of government market and government commitment to RLV producer may lead producer to focus exclusively on government needs, at the expense of capturing and creating commercial markets. Alternatively, RLV producer may choose to construct two vehicles or a single vehicle with optional strap-on boosters to accommodate heavy government payloads and medium commercial payloads.
2001	Medium EELV becomes operational	A maximum 10-percent cost savings from new MLV improves U.S. position in the commercial market, but not enough to hold off Russian and Chinese competition. To ensure success of its EELV program, DOD may avoid early participation on RLV flights, limiting the customer base for potential RLV investors
2001/2	Trade agreements with Russia/China expire	Unless new agreements are negotiated, U.S. launch providers find themselves at a severe pricing disadvantage. Without an RLV or greater than expected savings from a medium EELV, launch providers may find themselves unable to compete in the commercial market.
2005	Heavy EELV becomes operational.	A maximum 40-percent savings on new HLV results in substantial cost savings to the government. Potential for the development of a multipayload version, like the Ariane 5, for limited, expensive commercial use.
2005	Limited RLV flights commence.	RLV begins direct competition for flights with the Space Shuttle, the EELV family, and other ELVs.
2005	Last of the current generation of long-range ballistic missiles is produced.	Lack of development or production programs may result in loss of ability to make new ballistic missiles without significant startup costs and delays. Move of industry to all liquid-fueled boosters on the Space Shuttle, EELV, and future RLVs would all but eliminate domestic production of large solid rocket motors
2012	International Space Station is scheduled to cease operation just as a manned RLV replaces the Space Shuttle or block upgrades of the Shuttle commence	One of the few planning goals identified for the RLV is its ability to deliver passengers and cargo to the space station orbit. Life extension of the International Space Station seems likely, especially if operations are passed to a commercial venture.

SOURCE: Office of Technology Assessment, 1995.

Dr. WILLIAMSON. My testimony today draws on both those reports. To borrow an image from the coming holiday season, I am one of the Ghosts of OTA Past.

NASA's RLV program demonstrates that we have learned quite a lot about space transportation developments since building the Space Shuttle in the 1970s. Nevertheless, I have substantial doubts that the program will be successful in creating a new commercial launch system without continued significant financial support from the U.S. Government, after the risk-reduction phase of the program, and after the successful testing of the X-33.

The biggest hurdle is likely to be attracting sufficient private investment to create a viable privately owned and operated launch system.

Some RLV proponents seem to believe in the Field of Dreams theory of a space transportation market. Just build a system and the customers will come.

However, a private commitment of some 6 to 10, or even more billion, to assist them requires not a Field of Dreams but some very hard-nosed analysis and assessment by the financial community.

Investors will ask such questions as what other opportunities do they have for their investment dollars?

How large is the expected market?

What global and domestic competition would a commercial RLV face?

How resilient to failure will the RLV system be?

And what are the policy risks from the U.S. Government?

I want to take some of those items in order. For example, the expected market size.

In order for an RLV to be financially successful it will need new markets. Current markets would not sustain an RLV in my view.

In the future, some analysts suggest, a large market for space tourism might develop. Others have suggested the use of space transportation to solve the problem of hazardous waste disposal. However, it may take another decade of experience and considerable study to develop credible estimates of these or other proposed new markets for launch systems.

A related issue is what market is an RLV to serve?

NASA needs a relatively large vehicle—in other words, one that will carry a lot of payload into orbit. The private sector market is actually focused for the foreseeable future on much smaller payloads.

So there is this disjuncture between what the private sector would do if it were serving a primarily commercial market and what it might want to do to help serve NASA's needs.

Next there is a question of competition from other systems, including the evolved expendable launch vehicle that the DoD is funding.

Attempts to build an operational RLV will experience competition in the financial markets from existing launch systems.

Even if potential investors judge a future commercial RLV likely to be substantially cheaper than existing systems, they will be reluctant to commit funds unless they can see that the new system will capture sufficient market share, given other means of reaching space.

This economic reality will inhibit the flow of investment funds.

For example, the unexpected longevity of the Boeing 727s and 737s, or the McDonnell Douglas DC-9s has recently slowed the demand for new models of aircraft.

Company officials will not commit development funds, and they will not get the money from the banks for new aircraft unless there is considerable assurance of a market for it.

Overseas, as ha already been mentioned today, we face considerable competition from other countries who offer launch services on an expendable launch vehicle—vehicles.

For a variety of economic, institutional, and technological reasons, they are formidable competitors to the United States.

Another aspect of competition is the price that an RLV firm might be able to charge for launch services. Advocates of the RLV program suggest that RLV costs will be low enough to capture most of the available market.

However, it is unclear how much of the potential reduction in launch costs would actually be passed on to launch services' customers.

In order for commercial developers to amortize their development investment, they will need to charge initial prices much higher than their projected marginal price per launch in the future.

Hence, space transportation customers may not reap much price benefit from the investment in a new space transportation system for a number of years after it is operational.

Nevertheless, a U.S. firm offering RLV services at sufficiently low prices could capture a significant share of the world's commercial market for launch services.

Now I want to point to a couple of other items in the RLV program. One of them is the focus on developing SSTO technology.

The X-33 may be successful but not fulfill market requirements. Success of the RLV program will ultimately be measured in the size of the reductions in the price-to-launch payloads to orbit, not in the method or mode used to achieve those reductions.

Paper analysis carried at NASA and elsewhere suggests that a system capable of reaching orbit with a single stage may be the most cost effective way to reach space. However, these analyses depend on a number of technical and economic assumptions that may prove incorrect, including the cost of development, the scale of demand for space transportation services, and the size and reliability of the launch system.

It may turn out, for example, that a two-stage system will prove more cost-effective than SSTO when all the factors, including the projected market size and the cost of money, are taken into account.

I worry about the current overwhelming emphasis on SSTO technology and fear that SSTO is being oversold.

During the 1980s, I remind us, officials in this country stood by and watched Europe using expendable launch technology developed in the 1950s and 1960's capture increasing market share while we focused on the much more advanced and capable Shuttle.

Preoccupation of U.S. officials precluded—or clouded, rather, their market judgment. We should not make the same mistake twice.

I would urge that NASA also make modest but significant investments in examining the technology of two-stage systems while it pursues SSTO as its primary focus.

And finally, my testimony, while cautionary about the expectations for private development of a commercial RLV, should not be construed as negative about NASA's and industry's attempts to forge new relationships and to work toward developing a new, reusable launch system. Far from it.

The system resulting from the RLV program may not look or operate as we now envision, and as I have indicated it may not be an SSTO system; however, the potential for achieving substantial cost reductions and greater launch flexibility seems worth the moderate investment in new technologies both by government and by the private sector.

Even if the final result does not meet all the expectations of NASA, the White House, and Congress for its success, without this or a similar development program, we will never know what we might otherwise have achieved in providing a replacement to the Shuttle and reducing overall space transportation costs.

Thank you.

[The prepared statement of Mr. Williamson follows:]

Statement of
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before the
Subcommittee on Space and Aeronautics,
Committee on Science
U.S. House of Representatives
1 November 1995

Mr. Chairman, I appreciate the opportunity to testify today on space transportation issues, and in particular on the Reusable Launch Vehicle (RLV) Program, being managed by NASA with the active participation of the launch vehicle industry and some limited involvement of the Department of Defense (DOD). In May of this year, the recently closed Office of Technology Assessment (OTA) issued a report at the request of the Science Committee entitled *The National Space Transportation Policy: Issues for Congress*. This past August, OTA also issued a related background paper on the health of the lower tier suppliers of space transportation systems and subsystems, entitled *The Lower Tiers of the Space Transportation Industrial Base*. I was a member of the team that drafted these reports, which were directed by Christopher M. Waychoff. My testimony draws on, but is not limited to, these two recent OTA reports. It also draws on the series of reports on space transportation that OTA prepared for this committee and other committees of Congress between 1988 and 1990 (table 1) and my own analysis of U.S. space transportation policy.

Mr. Chairman, your letter of invitation asked participants to focus on four important questions with respect to NASA's and industry's RLV program:

1) Understand the technological risk reduction phase of the RLV program in terms of cost, technical difficulty and the key participants' roles under the Cooperative Agreements.
2) Determine whether sufficient funding has been requested by NASA to achieve the level of risk reduction considered necessary by industry partners, and whether adjustments in the promised funding curve are necessary or not.
3) Query the industrial partners in the RLV program with respect to their ability to proceed with private development of the RLV launchers, and determine under what terms and conditions these firms will be able to finance full-scale development.
4) Determine whether the RLV program being executed by NASA under the cooperative agreements could inadvertently become a traditional, NASA-pays-all procurement, and identify steps for Congress to follow in avoiding such a scenario.

Forthright answers to these excellent questions will help determine the potential for success of the RLV program. In order to chart future policy for the RLV program, it is also important to look beyond it at other launch-related research and development efforts by government and industry, both here and abroad.

U.S. Space Transportation Policy

For years, U.S. space transportation policy was confused and directionless, in part because too many competing interests within the U.S. government were allowed to spend federal dollars on promoting launch systems and concept studies in which they were interested. Agencies studied and advocated a profusion of possible launch systems. Federal space transportation policy lacked a clear focus. In fact, I think it is fair to say that during the 1980s the United States stumbled badly in crafting a workable national policy for space transportation. Among other things, U.S. space transportation policy,

which promoted the use of the shuttle for government and commercial payloads, allowed Europe to gain a strong market advantage in launching commercial satellites.[1] Only the shock of the loss of *Challenger* created the appropriate conditions to develop a more rational policy toward private sector launch systems.

The current Administration policy, first promulgated in August 1994, goes a long way toward resolving some of the previous conflicts, in part by establishing clear lines of responsibility and authority for the development of new launch systems. The policy gives to NASA the responsibility for development of reusable launch systems and to the DOD the responsibility for developing any new expendable launch systems that might be required for national security and other purposes. The policy continues to leave to the private sector the maintenance and improvement of existing commercial launch systems.

Nearly a year ago, as directed by the President, NASA, DOD, and the Departments of Commerce (DOC) and Transportation (DOT) submitted plans for implementing the policy. In accordance with the division of duties spelled out in the policy, NASA outlined its plans for developing a new resuable launch system, with the full participation of industry, and DOD summarized its intention to develop a new evolved expendable launch vehicle (EELV) system. According to NASA's current plan, the RLV would be designed eventually to carry passengers to and from orbit, in part to replace the space shuttle. Both new systems have as a central goal the reduction of launch costs. Of the two, NASA's program, which attempts a revolutionary step in space transportation, is much more technically challenging and carries much greater risk. Yet, if successful, it might also result in a much greater payoff in reducing launch costs. By investing in new launch vehicle technology, the DOD EELV program could assist the U.S. private sector become more competitive globally, although the reductions in cost to

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[1] See for example, the discussion in U.S. Congress, Office of Technology Assessment, *International Cooperation and Competition in Civilian Space Activities*, OTA-ISC-239 (Washington, DC: U.S. Government Printing Office, July 1985), pp. 138-143.

reach orbit may be relatively modest, at least for the moderate-sized payloads that constitute the greatest commercial market.

The Reusable Launch Vehicle Program

The agenda of NASA's RLV program demonstrates that we have learned quite a lot about how to tackle a new space transportation development program since building the space shuttle in the 1970s. The RLV program now emphasizes the importance of reducing the costs of operations, and of depending much more on industry for design and development decisions. NASA has also given greater scrutiny to the launch services marketplace, a necessary concern if industry is to take over development of the operational vehicle that RLV proponents expect to follow the X-33 phase of the RLV program early in the next century. The program's focus on testing the viability of technologies suitable for reaching orbit using a single stage (SSTO) seems an appropriate goal for a program attempting to establish a revolutionary step in space transportation. Nevertheless, I have substantial doubts that the program will be successful in creating a new commercial launch system without continued significant financial support from the U.S. government after the risk reduction phase of the program and after successful testing of the X-33.

In my view, the biggest new step that NASA is attempting to take with this program is the final one. That step depends on attracting substantial private investment to create a viable, privately-owned and operated launch system from which NASA, and perhaps also DOD, will purchase future launch services. Some RLV proponents seem to believe in the *Field of Dreams* theory of the space transportation market—just build the system and the customers will come. However, a private sector commitment of some $6 billion to $10 billion, or possibly more, to a new system requires not a "field of dreams," but some very hard-nosed analysis and assessment by the financial community. Investors will ask questions such as: How many years will it take before the investment earns a

profitable return? What other opportunities do they have for their investment dollars? How large is the expected market and what is the ratio of commercial payloads to government payloads? What global and domestic competition would a commercial RLV face? What are the technical risks? How resilient to failure will the RLV system be? What are the policy risks? What are foreign governments doing for their launch industry?

The following paragraphs focus on these questions regarding the RLV progam:

- *Expected Market Size.* Market size will be an important determinant in garnering investment dollars for a commercial RLV. The larger the prospective market and the fewer the competitors, the more likely is industry to invest. Seen from the perspective of U.S. companies, the current market for payloads is composed of three components: 1) commercial U.S. and foreign satellites, primarily communications satellites; 2) DOD payloads up to about 20,000 lbs to low Earth orbit (LEO); and 3) NASA science payloads of similar size. The very small existing market for human spaceflight is currently satisfied by NASA's space shuttle; the even smaller market for large robotic national security payloads is satisfied by DOD's Titan IV launcher.

  Although future U.S. and international demand for RLV-size payloads is highly uncertain, based on existing market needs (primarily communications and remote sensing satellites), most analysts expect only modest growth over the next decade or two.[2] For launching most robotic payloads, the world supply of space transportation services will far exceed the available demand.

  The financial risk of developing an RLV could be markedly reduced if large new markets for space transportation services could be developed and captured by a commercial RLV. For example, over the next decade and a half, the only demand for human space transportation services is to replace the crews on the Russian *Mir* space station (near term) and to build and operate the planned future International Space

[2] Demand for launching small payloads of 500 to 2000 lbs. could grow substantially with the development of LEO communications satellite systems. Most of this market could be served by much smaller launchers.

Station. In the future, some analysts suggest, a large market for space tourism might develop. Others have also suggested the use of space transportation to solve the problem of hazardous waste disposal.[3] However, it may take another decade of experience to develop credible estimates of these or other proposed new markets for launch services.

This committee is justifiably concerned about a launch vehicle development program that could result in a long-term burden on the taxpayer. The taxpayers' willingness to commit tax dollars to developing new space transportation capability will depend in large part on the rationale for the development of an RLV. If the primary justification is to support government requirements, then we can expect government investment to be large compared to private investment. If the commercial market will be much larger than the market for government payloads, then fewer federal dollars should be committed.[4]

One problem launch systems planners face is choosing the system's optimum payload capacity. Sometime early in the next century, NASA will need a replacement for the space shuttle, which is aging, if NASA is to continue to support the planned International Space Station and other projects requiring a launch system capable of transporting humans to and from orbit. Every user of space services would also benefit from substantially reduced space transportation costs, if they can be achieved. NASA's target, identified by NASA's January 1995 Cooperative Agreement Notice (CAN), is 25,000 lbs. to a 200 nautical mile orbit, inclined to 51.6 degrees (the International Space Station orbit), which requires a substantially larger and more costly vehicle than appropriate for the existing commercial payload market. By contrast, the needs of most commercial satellite owners would be served

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[3] The Commercial Space Transportation Study Alliance, "The Commercial Space Transportation Study: Executive Summary, 1994.

[4] See U.S. Congress, Congressional Budget Office, *Budget Treatment of NASA's Advance Commitments to Purchase Launch Services*, CBO Memorandum (Washington, DC: Congressional Budget Office, June 1995) for a discussion of various mechanisms to assist the private sector in developing an operational RLV.

by a vehicle carrying about 20,000 pounds to geostationary transfer orbit. The disparity between commercial interests and NASA's needs for an RLV argue for substantial government investment in an operational RLV.

- *Competition From Other Systems, Including the EELV.* Attempts to build an operational RLV will experience competition in the financial markets from existing launch systems. Even if potential investors judge a future commercial RLV likely to be substantially cheaper than existing systems, they will be reluctant to commit funds unless they can see that the new system will capture sufficient market share, given other means of reaching space. This economic reality will inhibit the flow of investment funds to an RLV. For example, the unexpected longevity of the Boeing 727s and 737s, or the McDonnell Douglas DC-9s, has recently slowed the demand for replacement aircraft and thereby inhibited new aircraft development in the same class. Company officials will not commit development funds for a new aircraft model unless there is considerable assurance of a market for it.

  The DOD's EELV program, if successful in reducing the cost to the customer for space transportation by 10 to 20 percent, will further increase the reluctance of investors to commit their funds to an RLV. In addition, the DOD states that it has no need for an RLV to launch its payloads. DOD's primary reason for investing funds in the EELV program is to reduce the costs of launching large payloads that can now fly only on the Titan IV.

  Finally, McDonnell Douglas's recently announced plans to build a Delta 3 medium lift launch vehicle suggests that considerable strength still remains in the marketplace for the development and use of expendable launch vehicles. In addition, Lockheed Martin has invested in improvements the Atlas launcher to make it more competitive, internationally.

Overseas, several countries offer launch services on expendable launch vehicles. For a variety of economic, institutional, and technological reasons, they are formidable competitors to the United States. Europe's Ariane launch vehicle now holds more than 50 percent of the commercial market for launch services. The European Space Agency is developing the Ariane 5 heavy lift launch vehicle system and has recently agreed to invest in continued improvements to it. China, Russia, and Ukraine have capable launch vehicles that will capture an increasingly large market share, particularly given the likely disappearance of launch quotas early in the next century. Launch companies in these countries will continue to pose competitive pressures on U.S. firms and on Arianespace. Finally, both India and Japan are investing heavily in expendable launch systems and might offer commercial services in the future.

Another aspect of competition is the price that an RLV firm might be able to charge for launch services. Advocates of the RLV program suggest that RLV costs will be low enough to capture most of the available market (in other words, that portion of the market not reserved for national systems). However, it is unclear how much of the potential reduction in launch costs would be passed on to launch services customers. In order for commercial developers to amortize their development investment, they will need to charge initial prices much higher than their projected marginal price per launch. Hence, space transportation customers may not reap much price benefit from the investment in a new space transportation system for a number of years after it is operational. Nevertheless, a U.S. firm offering RLV services at sufficiently low prices could capture a significant share of the world's commercial market for such services.

- *Reducing Technical and Operational Risks.* On the whole, the program to reduce technical risks and to develop the X-33 experimental vehicle is a reasonable effort

that seems to be on target. For example, in addition to the expected concerns about the operational use of new materials and propulsion, the program has focused considerable effort on reducing the operational costs associated with space transportation systems. In 1988, OTA published a short technical report on reducing launch operations costs, which reported that launch and missions operations costs for the space shuttle may comprise more than 40 percent of the cost of each flight.[5] New reusable systems could experience similar high operational costs unless considerable research and development effort is expended to reduce them. NASA appears to recognize this.

In my view, the DC-X program, which NASA now operates, has had the right focus. It is a low-cost test program that was structured to find ways of reducing operational costs, using existing technologies in a program that emphasizes extensive testing in measured small steps to reduce technology uncertainty. In the near future, NASA will begin testing the DC-XA. Specifically, NASA will use the DC-XA to test various technologies that might be used in the X-33 SSTO demonstration launch system. It will be important for NASA to continue the spirit of the DC-X program as it tests new launch technologies. It should focus not only on improving performance, but also on improving maintenance and reducing turnaround time.

Technological improvements for an RLV should include design elements that not only reduce the chance of failure (i.e., assure high reliability) but also improve the potential for recovering from failure, thereby avoiding lengthy system stand downs. Such technologies, which include built-in test equipment, automated test and

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[5] U.S. Congress, Office of Technology Assessment, *Reducing Launch Operations Costs: New Technologies and Practices*, OTA-TM-ISC-28 (Washington, DC: U.S. Government Printing Office, September 1988), p 13

inspection, fault-tolerant computers and software, are important components of modern aircraft design.[6]

In the 1970s, shuttle development was continually squeezed financially by the Administration and by Congress. In order to meet development goals, NASA responded by cutting spending on technologies that would have reduced long-term operations costs in favor of reducing upfront costs. In the RLV program Congress will have to oversee NASA's operation closely in order assure itself that NASA continues to focus on reducing long term system costs as well as reducing future development costs.

RLV Program Focus

NASA's RLV program, which focuses on developing SSTO technology for the experimental X-33, may be technically successful but not fulfill market requirements. Success of the RLV program will ultimately be measured in the size of the reductions in the price of launch payloads to orbit, not in the method or mode used to achieve those reductions. Paper analyses carried out at NASA and elsewhere suggest that a system capable of achieving orbit with a single stage *may* be the most cost effective way to reach space. However, such analyses depend directly on a number of technical and economic assumptions that may prove incorrect, including the costs of development, the scale of the demand for space transportation services, and the size and reliablity of the launch system. A commercially viable new launch system will also depend on reducing the system development and construction costs to the point that the upfront costs, combined with the cost of money over the time of development and initial operational costs, allow a private company to earn a profit after relatively few years of system operation.

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[6] See the discussion in U.S. Congress, Office of Technology Assessment, *Reducing Launch Operations Costs: New Technologies and Practices*, OTA-TM-ISC-28 (Washington, DC: U.S. Government Printing Office, September 1988), ch. 4, for a list of technologies that would reduce operational costs of an RLV.

The country's experience with the unexpected high costs of the space shuttle have made everyone a bit gun shy about investing in reuseable vehicles requiring more than one stage. The partially reusable space shuttle system has three major flight components—the orbiter, the external tank, and the solid rocket boosters—each of which requires a large dedicated ground system and large numbers of support personnel. Seen in this light, SSTO is extremely attractive. However, it may turn out that, given the technology we are able to develop by the turn of the century, a two-stage system will prove more cost-effective than SSTO when all the factors, including projected market size and the cost of money, are taken into account.

I worry about the current overhwelming emphasis on SSTO technology and fear that SSTO is being oversold. During the 1980s, officials in this country stood by and watched Europe, using expendable launch technology that was originally developed in the 1950s and '60s, capture increasing market share while we focused on the much more advanced shuttle. The preocupation of U.S. officials with advanced technology clouded their market judgement. We should not make the same mistake twice. I would urge that NASA also make modest, but significant, investments in examining the technology of two-stage systems, while it pursues SSTO as its major focus.

Payload Costs

Although this hearing focuses on the RLV program, it is worth noting that future demand for launch services will also depend on the cost of payloads. Today's costs for developing new payloads will inhibit the development of higher launch services demand, even if launch services become very cheap. Today, it still costs between $25,000 and $250,000 per pound and even more to build a satellite.[7] That compares with costs of

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[7] U.S. Congress, Office of Technology Assessment, *Affordable Spacecraft: Design and Launch Alternatives*, OTA-BP-ISC-60 (Washington, DC: U.S. Government Printing Office, January 1990).

about $10,000 per pound to launch the payload into orbit (launch costs vary considerably, depending on the orbit and total size of the payload).

NASA, DOD , and industry have various programs aimed at reducing payload costs. In my view, these programs need greater emphasis if the United States is to reap all possible benefit from reduced space transportation costs.

The Need for Consistent Policy and Follow-Through

In my 16 years at OTA, analyzing space policy for this and other Congressional committees, the most consistent concern I heard from the private sector regarding the commercialization of space technology was the lack of clear, consistent government policy. Once firms understand a new policy, and feel convinced that it will continue for a reasonable period, they can craft appropriate investment and marketing strategies. The U.S. private sector, is, afterall, extremely capable of designing competitive strategies to take best advantage of the marketplace and government policy. However, uncertain or rapidly changing policy cuts away at industrial confidence and causes the financial markets to reduce their financial exposure to the market in question. Hence, in pursing an RLV program, it will be extremely important for Congress and the Administration to establish clear policy and follow through with the necessary funding to support the policy. The sad experience with the attempts during the 1980s to commercialize the Landsat program should provide sufficient cautionary experience for anyone interested in the development of new markets in space.[8] In the next few years, we are likely to see the development of a truly commercial remote sensing industry, but if it does occur, it will result for the most part from the persistence of private interests, not from government policy.

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[8] See, for example, the analysis of the Landsat program in U.S. Congress, Office of Technology Assessment, *Civilian Satellite Remote Sensing: A Strategic Approach*, OTA-ISS-607 (Washington, DC: U.S. Government Printing Office, September 1994), ch. 3. See also U.S. Congress, Congressional Research Service *The Future of Land Remote Sensing Satellite System (Landsat)*, 91-685 SPR (Washington, DC: The Library of Congress, Sept. 16, 1991).

As the RLV program proceeds, NASA will have to continue to demonstrate that its new approach to launch system development is working. It will also need the firm support of Congress, in both funding and policy, in order to assure the best outcome for a new launch system.

Conclusions

My testimony, while cautionary about the expectations for private development of a commercial RLV, should not be construed as negative about NASA's and industry's attempts to forge new relationships and to work toward developing a new reusable launch system. Far from it. The system resulting from the RLV program may not look or operate as we now envision, and, as I have indicated, it may not be an SSTO system. However, the potential for achieving substantial cost reductions and greater launch flexibility seems worth a moderate investment in new technologies both by government and by the private sector. Even if the final result does not meet all of the expectations of NASA, the White House, and Congress for its success, without this or a similar development program, we will never know what we might otherwise have achieved in providing a replacement to the shuttle and reducing overall space transportation costs.

Table 1.—Office of Technology Assessment Space Transportation Reports

1995 *The National Space Transportation Policy: Issues for Congress*

1995 *The Lower Tiers of the Space Transportation Industrial Base*

1990 *Access to Space: The Future of U.S. Space Transportation Systems*

1990 *Affordable Spacecraft: Design and Launch Alternatives*

1989 *Big Dumb Boosters: A Low-Cost Transportation Option?*

1989 *Round Trip to Orbit: Human Spaceflight Alternatives*

1988 *Reducing Launch Operations Costs: New Technologies and Practices*

1988 *Launch Options for the Future: A Buyer's Guide*

Mr. SENSENBRENNER. Thank you very much, Dr. Williamson.

I would like to thank everybody for the really meaty testimony that they gave. This has been one of the better hearings that I have participated in since I have been on the Science Committee in terms of actually clearly defining issues as well as focusing on why we need to support some type of Reusable Launch Vehicle.

Let me begin by commenting that everybody on this Subcommittee supports the concept of the RLV. We fully funded the X-33 in our authorization bill, and in the previous Congress we supported the reprogramming of the initial funds into the X-33 program.

So this is a very exciting technology. It is something that I think we on the Subcommittee want to make sure gets completed. The best way to complete it is for it to stay on time and on budget.

We all know the problems of cost overruns. That is what gets me to one of my primary concerns.

First I would like to ask Dr. Mansfield and Col. Payton a couple of questions.

The funding profile which NASA has announced and has submitted to us for the X-33 program amounts to $43 million for fiscal 1996, $147 million for fiscal 1997, $340 million for fiscal 1998, $350 million for fiscal 1999, and $365 million for fiscal 2000.

Col. Payton, when you briefed the Technology and Commercialization Advisory Committee, which is called "the TCAC," you suggested increasing the fiscal 1996 appropriation from $43 million to $102 million; increasing the fiscal 1997 appropriation from $147 million to $252 million; decreasing the fiscal 1998 from $340 million to $310 million; decreasing the fiscal 1999 from $350 million to $325 million; and decreasing the fiscal year 2000 appropriation from $365 million to $208 million.

Now both of these recommendations suggest that we spend the same amount of money in total, but it appears that Col. Payton is suggesting advance-funding the program, and the information that we have received from Mr. Minor and Rockwell's testimony suggests that the program is under-funded in the beginning.

Now NASA is kind of bidding against itself in time lines, and I want to get this straightened out. So could you help us?

Dr. MANSFIELD. Well, sir, the misphasing of the program has been noted by a number of the witnesses. The RLV program, the X-33 program, could be successful with the funding profile that we originally presented to you, but it is very, very risky.

Industry has told us that.

They have never seen a program succeed that did not have 60 percent of the funding in 40 percent of the time. We have got 30 percent of the funding in 40 percent of the time, roughly, and that means we run a risk of suppliers being late; we run a risk of not being able to do enough of the early work up front.

However, the budget we gave you represented our need to give you a balanced program across NASA. We do not have a NASA budget and an RLV budget. The RLV budget is in the NASA budget, and we have had to give you a balanced budget.

The one that was presented in the President's budget this year represented our best attempts to balance that.

Since then, we have gone through agency-wide reductions in our zero-based review and we are addressing right now the need of

whether the 1997 request will have to be higher than what we suggested originally. But it has not been done yet, and the requests will come accordingly.

Mr. SENSENBRENNER. Mr. Mansfield, we have heard complaints about the 1996 request. One of the reasons why we are all here today is because the Senate Appropriations Subcommittee plussed up the account by $20 million.

I have had several conversations with Administrator Goldin who wants to stay at the $43 million figure. Now, you know, I do not want to see this program get swallowed in a bunch of cost overruns, because if that happens it ain't gonna' get completed, and we all know that.

So trying to get to what is needed to do the job is rather difficult when Col. Payton says that apparently we have got to do some advance funding. You have intimated that, and Mr. Goldin tells us exactly the opposite.

You know, to further my confusion and the confusion of a lot of us in this room is that Mr. Payton's brief to the TCAC ended up with a quote from Administrator Goldin saying that he'd cancel other programs to protect Advanced Space Transportation.

Now we all know that that has not been done. So, you know, I do admire broken-field running, but that should be on the football field, not when we are talking about budget figures.

Dr. MANSFIELD. Well, Administrator Goldin's comments had to do with the 1997 budget and beyond, not the 1996 budget.

The request for 1996 is adequate to do our job. Let me explain what the risk is. We will do our selection in July for the down-select for the X-33 team.

Between then and the end of the fiscal year, the winning team will be in a startup mode.

With some planning—a good part of the initial investment we believe, but I certainly invite the comments of our industrial partners—with good planning, some of the expensive investments and orders for materials and things like that could be put off until 1997 instead of 1996.

There is risk with that because the risk is that the suppliers will not deliver on time, and you need to make your orders early. We lose that. We lose that. But that is really what the risk is.

Mr. SENSENBRENNER. Yes.

Now one other question of NASA, and then I will ask a couple of questions of the industrial partners.

Both the original NASA proposal and the time line that Col. Payton gave to the TCAC put in a figure for fiscal year 2000, which is after Phase II of the X-33 program has been completed.

The original NASA proposal had $365 million. The Payton TCAC memo had $208 million.

Now I had assumed that this was the beginning of the down payment on Phase III. But if we are moving approximately $150 million into the pre-fiscal year 2000 time line, are we robbing Phase III to hide a cost overrun for Phase II?

Dr. MANSFIELD. That is a very good question.

First I must say that the later years of the NASA budget runout that we gave you had progressively less definition. The program for

the X-33 was funded I believe through 00 and had no money in 01. I believe that is correct, isn't it?

The money that shows in the 01 budget is not defined as part of the X-33 program and not intended to cover an overrun for the X-33 program.

What it was intended to cover is any potential possible government share in a phase III. For instance, it may be—this is not a plan, and I am not suggesting it, but it may turn out that the sensible phase III full-scale RLV needs a new engine, and it might be appropriate for the government to stand up to funding all or part of that new engine.

Mr. SENSENBRENNER. Um-hmmm.

Dr. MANSFIELD. In order to at least make those decisions—or those discussions have some basis in our future fiscal planning, we included that runout in there.

Mr. SENSENBRENNER. Okay.

Dr. MANSFIELD. But it isn't planned for the X-33——

Mr. SENSENBRENNER. Now——

Dr. MANSFIELD. [continuing] and if it is ever spent on the X-33, I will probably be in the street because I promised Dan what it was going to cost.

Mr. SENSENBRENNER. I have one question of the industry panel:

If there is an advanced funding of the runout of the billion dollars—in other words, if we spend more in the earlier fiscal years and less in the later fiscal years, would industry be willing to increase its share of the pot commensurate to the increase in the money that the Taxpayers through NASA would be putting in?

Mr. MINOR. I will take a shot at that, if you would like.

I think obviously we did, from looking at traditional funding and development of programs, did strongly suggest that there be more funding up front. I think, at least from where we are in industry from the standpoint of putting money into Phase II, that all of the industry partners are putting money in. I think from the standpoint of Phase II, our question to the panel, the subcommittee, and to NASA is, what kind of commitments is the government going to make with respect to Phase III as we move into phase II?

Certainly I would think traditionally of course Phase II is more of an X-plane development program where the government should take the large share of the risk. I think industry, at least from our standpoint, would predominantly look at things like backup technologies, et cetera, to put its money in. But we would very much like to hear the commitments of where the government is going as we move into phase II for phase III.

Mr. SENSENBRENNER. Does anybody else on the industry panel want to answer my question?

Are you folks putting up more money if you want us to put up more money?

Mr. ORDAHL. Well let me, Mr. Chairman, comment briefly on the subject of the profile of the funding also, because we use the DC-X as one of our more successful program models. We of course adjusted those fundings for the kinds of work which we felt were required in the X-33; but the DC-X program did follow the fast prototype approach that I mentioned earlier.

So it was the closest thing that we had. It was using this type of modeling that we came up with, of course the requirements that more money be spent in the earlier years as was earlier mentioned.

So we certainly feel that for the success of the program in terms of its total cost, that coming as close as you possibly can to the appropriate best-planned profile is the right way to go.

Relative to our investments, clearly as Mr. Minor has said, we agree that any commitments that the government makes earlier, more substantially, whatever, relative to phase III or phase II will certainly assist us.

We are going through a lot of reviews relative to the kinds of commitments that we are willing to make on this program. Those are clearly not completed yet at this time, but any earlier larger and fuller commitments will help, certainly.

Mr. SENSENBRENNER. Mr. Gordon?

Mr. GORDON. We at Lockheed Martin certainly agree that typically programs are more front-loaded in terms of cost. We have to make commitments for long lead kinds of items.

The maximum risk reduction that will result from the X-33 program will come from flying as early as possible so that we can reduce all of those perceived risks that might allow us to go out and attract financing in the future.

I would say that there is a way to uncouple in one sense the phase II investment from the phase III investment and the need for private financing by the government accepting a larger share of phase II. Then we do not have the problem of trying to figure out how we are going to recover all of our money through Phase II and Phase III, because we look at each investment kind of incrementally in terms of the opportunity costs and the other ways that the corporation could invest its money to the benefit of its shareholders.

Let me say that we will invest. The Skunk Works, especially, really believes in the Cooperative Agreement process. We think it provides a lot of flexibility and opportunity to restructure and redirect the program, and that is typical of the way the most successful Skunk Works' programs have operated in the past.

So within our normal kinds of resources, we are certainly prepared to invest in Phase II.

Going beyond our normal kinds of investments in programs, I would say then that we would have to have some sort of commitment as to what the promise is for Phase III.

Mr. SENSENBRENNER. Thank you. My time is expired.

The gentleman from California, Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman.

Mr. Chairman, the line of questioning that you have pursued is undoubtedly the most important aspect of our role in this process. The ability to have reliable development estimates and schedule estimates, and the reliability of the Congressional commitment to these schedules is from my own experience with other programs a key to maintaining an effective program that can be controlled as to cost.

I am concerned about the indication that we have not adequately provided for the early funding of this program. I wonder if that has not been driven by the budgetary—the larger scale budgetary re-

strictions which have caused NASA's five-year outlook funding to be seriously gone down.

I would like to ask this question:

If we were to deal with this program as we have with the Space Station and do a five-year authorization to completion for this program at the appropriate levels on a year-by-year basis, hopefully getting closer to that 60 percent funding during the first 40 percent rather than the 30 percent that we have, would that make industry somewhat more enthusiastic about perhaps taking a little larger share of the burden in this situation?

And, would it—would it do more than that? Would it provide greater certainty that the program would actually be completed, which would affect industry's thinking, I would presume.

Mr. MINOR. It would certainly say the funding profiles that I think all of us have talked about would give us a great deal more confidence that the X-33 program could be done on time. And of course being on time means being on budget.

I think that would certainly positively affect my company with respect to the X-33 program. It would make us much more enthusiastic about it.

Mr. BROWN. Do the others share that point of view?

Mr. GORDON. We certain—at least I certainly do.

Mr. ORDAHL. I guess I would second that, as well. I think it would build more confidence in the investment community out there that indeed were dedicated to having a successful RLV program.

Indeed, I think having the longer commitment to the RLV program would have some positive benefits. Mr. Chairman, you were talking about why we might want to have more money in 1996. It strikes me just the way the budgeting process works within the government that we might not have enough money to take off those things in 1997, as Mr. Mansfield implied, yea, we cannot ramp up all that quickly, but we do have to make some long-term commitments.

If the budget is not there in 1997, then we are delayed in making those commitments. So the longer term approach to how we handle RLV would seem to be positive.

Mr. BROWN. Mr. Mansfield, you hinted at the possibility that there needed to be a review of the zero-based funding and possibly some increases; and that Mr. Goldin had a different point of view.

I am really trying to understand that situation a little bit. I get the feeling that Mr. Goldin goes into discuss his budget with the OMB and the White House and presents a funding profile for NASA that does the job, and he gets beat over the head and forced to take a lower budget, and then he like a good soldier defends that lower budget even though he did not recommend it originally.

Maybe you have not been beat over the head enough yet, so you are still defending a higher budget.

[Laughter.]

Mr. BROWN. Would there be any veracity in that kind of an analysis?

Dr. MANSFIELD. It is partly true, sir. I have certainly been beaten on the head enough.

[Laughter.]

Dr. MANSFIELD. In fact, the formulation of the President's budget is a collaborative effort, and we are clearly given direction of what not to ask for. We cannot ask for the moon. It just makes everybody's problem harder.

Mr. Goldin's problem is to satisfy all the requirements that Congress and the President have put on him within a budget that is limited by reality now in the face of the budget deficit. That is really a hard problem.

It may not be true—Mr. Goldin has said that it may not be possible to do all of our programs without cancelling something. However, he is committed—he has told us he is committed to presenting to the President and to Congress a balanced program.

As a result, we do not have the option of moving money from other programs in the year 1997 and 1998 into the RLV program for the simple reason that it stops other programs dead that we have committed to you.

So we have been trying to do a balanced program. It is as difficult as you intimate that it is, sir.

Mr. SENSENBRENNER. The gentleman's time has expired.

The gentleman from Texas, Mr. Stockman.

Mr. BROWN. You do not want me to pursue this line of questioning, do you?

Mr. SENSENBRENNER. If you would like a second round, I would be happy to accommodate you then.

Mr. BROWN. I understand, Mr. Chairman.

Mr. STOCKMAN. Thank you, Mr. Chairman.

I am an enthusiastic supporter of the program. However, I too have concerns about historically how Congress gets enthusiastic about something, and then of course we have something that we call "elections" and the whole paradigm shifts to a different philosophy, and then industry is left hanging there.

Is there something in terms of what Mr. Walker has proposed in the past in terms of tax incentives or tax breaks that the industry would be more amenable to help out on the project?

Mr. Minor?

Mr. MINOR. Well, you know, as we have talked on government support, we welcome some form of tax support would be as welcome as some sort floor market. We are not being specific on which combination of the above, but I think everybody at the table realizes that what industry is faced with, particularly as we move from phase II to phase III, is we must make this a good business deal. That's the bottom line. And certainly some sort of tax legislation or support would be one of those elements that would help make this a good business deal.

So the answer would be, yes.

Mr. STOCKMAN. I know a lot of times that companies are given tax abatements and things like that from local communities, and I guess what I am searching for is to see if, not only could we help you out in terms of monetarily direct funding, but maybe if we could make some arrangements like the local communities also do when they are trying to get a project off the ground, even if it is short-term. Maybe you can recoup some of your investment through that way, Mr. Mansfield?

Dr. MANSFIELD. That is really correct, Mr. Stockman.

We have begun to look at these problems. Col. Payton and I expected that we would not need to have a general agreement on solutions like this until it became necessary to fund Phase III around the year 2000.

But our industry partners have urged us to get this issue on the table between industry, OMB, CBO, the budget committees, the appropriations committee, this committee, well before that time.

So we can understand if there is a basis, any basis in law that could be offered to give the kinds of guarantees that they are worried about.

Their worry is, it has been told to me, is they are afraid that the same thing will happen to them that happens to the Chinese and Russians; that even though they have a lower price, for reasons—for good reasons of government, the business goes elsewhere.

What they could not have happen here, what would devastate them, is if they had the ability to launch U.S. Government satellites and, for reasons of national security, one thing or another, we kept other lines open.

They need a guarantee that, if they have got the lowest price and they have got a good product, that we will not find another reason to put the business elsewhere.

That will be our challenge. They have urged—our business partners here have urged us to get on with this, and we believe that that is just the right thing to do. We expect that they will be able to take the lead in bringing us all together to discuss this issue.

Mr. STOCKMAN. Well one of the things also, too, I was kind of curious about is the ability—should we consider cancelling other contracts in order to give the incentives to industry to invest more heavily into private launch vehicles?

Dr. MANSFIELD. In my opinion—well, this has never been raised at NASA—in my opinion, we don't know enough yet. I mean, it could be that we will fly the X-33 and find that there is nothing there; that there is not enough—that we have not made enough technical progress to go on with this.

So in our view, it is not proper to ask those questions until we know more about what we are going to get in the future.

But whether we should continue with—for instance, we have spent for a single, our largest launch vehicle, we spent on the order of $1.4 billion a year, DoD does, I think? You know, it is clear that if we could offer that service for a lot less that the government would probably look at that, and our industrial partners would want that to happen.

Mr. STOCKMAN. One of the questions that keeps popping up in my head while we are discussing all of this, and I do not know, maybe it is a naive question, I do not know, but are we developing——

[A buzzer sounds.]

Mr. STOCKMAN. My, that was quick.

Mr. SENSENBRENNER. The gentleman's time has expired. Hopefully not the gentleman, but just his time.

The gentleman from Texas, Mr. Hall.

Mr. HALL. I thank you, Mr. Chairman.

You know, always the long-term goal is to transfer this to private industry and let the marketplace work its will. It is easy to say, and it is nice to talk about, but it is a very difficult thing to do.

How much—I guess Mr. Williamson would be the one I would ask—how much do you estimate the development of an operational RLV would cost if it were financed completely by the private sector, as distinguished between it being financed by the Federal Government?

Dr. WILLIAMSON. I do not have a good answer for that——

Mr. HALL. It was not a very good question.

[Laughter.]

Mr. HALL. But it is the one they put down here for me to ask you, so——

Dr. WILLIAMSON. No, it is a good question because we ought to have a good sense of what these programs are likely to cost in the future, because after all we are talking about how to finance such a project.

The estimates that I have seen that have come both from NASA and from industry range between $6- and $10 or $12 billion for the full development.

We will know a lot more about potential costs, as I think Jack Mansfield suggested, at the end of the X-33 program when you really see what technologies you are dealing with.

It is sort of a sleight of hand to try to do very detailed estimates at this stage.

Mr. HALL. I might ask any of the gentlemen in industry that same question, if you have some input.

Mr. GORDON. Mr. Hall, I don't think there would be a dramatic difference. I have asked the same question of my people, and I am told that the payloads that we would want to do for the commercial part of the business would be about the same size as what we would need for Space Station resupply, for instance.

So that kind of sets—if you are going to try to get 25,000 pounds to low-Earth-orbit and you size the payload bay, that pretty well sizes the vehicle. To me, that is the whole issue.

Private versus government funding might have more to do with oversight and regulation. I think NASA is on a path to try to leave us alone to do the best we can on developing the vehicle with minimum interference.

I do not see a big change in the two approaches.

Mr. HALL. It takes a pretty long-term commitment to use RLV if industry would be able to attract enough private financing to develop it, for instance, wouldn't it? Certainly that is a good statement?

Mr. GORDON. Well, I mentioned in my oral testimony and also my written comments that the Skunk Works has been at this for about three years.

We took on affordable access to space as being potentially a commercial business venture, but the fundamental assumption in all of that was that we would be able to go out and get launch guarantees.

In other words, we would have a guaranteed market. From all of the people that we have talked to in the financial community, we just do not see much hope.

Mr. HALL. Would that guarantee be a long-term usage commitment by the government?

Mr. GORDON. Yes, at least for a period of time.

Mr. HALL. And if the government should make that commitment, what type ceilings should they insist on the prices that's charged? What are some of the provisions like quantity price discounts and all that that you work with day in and day out? That would all be a part of the agreement, I guess?

Mr. GORDON. That would all have to be a part of the agreement.

We viewed the $2.5 billion of Shuttle launch money as being money that, if it were diverted in part to sustaining the Shuttle because you have to do a transition, and also then to allow us to guarantee a certain number of launches per year that would replace Shuttle; and then at the end of five years, then there would be a whole different pricing structure.

But there would have to be a period of time where we would recover our investment.

And Indeed there is a problem for Congress, frankly, in that now we have a dual pricing structure and the government typically goes after the lowest cost, and we have competitive kinds of things that would have to be dealt with.

Mr. HALL. Mr. Ordahl, do you have any comment?

Mr. ORDAHL. Well I was just going to comment that again I generally agree with what Mr. Gordon has said.

We certainly—I certainly think, and our plans have been that this program be developed generally along commercial lines.

In other words, there would not be a lot of government oversight and things of that nature. That is the way most of our cost estimates have been put together.

However, it is still a very large and significant program investment. I think on the order of numbers we have been using is something on the order of $8 billion for the full operational system.

That is a huge investment, and one which at least the government sector that I am involved with works very hard and long on in making those kinds of decisions.

That is why I really support the idea that was discussed by Mr. Mansfield here earlier about a working group to face the issues that we are talking about to try to see how much progress can we make on how we are going to be able to work with the government sector on those payloads that the government would intend to fly on such a vehicle, realizing that this vehicle will be used for both government and commercial-sector launches.

We do need to figure out how that commitment can be made, just like any commercial company will make commitments if it is involved in a long-term development with a supplier, for example, of how its payment schedules would go and how much it is willing to pay up front in order to help get a program going, and that sort of thing.

We get very involved in a total process here. It is difficult, but we need to work on it.

Mr. SENSENBRENNER. The gentleman's time has expired.

Mr. HALL. I yield back my time.

Mr. SENSENBRENNER. The gentleman from Florida, Dr. Weldon.

Mr. DAVE WELDON [FLA]. I thank the chairman.

I would agree with the chairman that this has been one of the more informative and enlightening hearings, and I want to thank all of you for your comments. They have been very helpful for me to get a better understanding of what some of the problems are in us doing what we are trying to do in developing a new Reusable Launch Vehicle.

I have a couple of questions that pertain to the business that we are engaged in in my District, which is the launch business.

That is, as most of you are aware we have had a failure of a CONESTOGA launch vehicle, and then we had the failure in August of the Lockheed vehicle.

I am curious about who makes the decision in terms of where we test these new launch vehicles? Is it a government decision? Is it a NASA decision? Is it going to be an industry decision?

Is anybody doing any risk assessment calculations as part of it?

Dr. MANSFIELD. We certainly are, sir. The government is helping industry with this. The X-33 will be tested almost certainly from government test facilities.

How the full-scale RLV is tested is a matter for the future. It is such a large vehicle, there are few places that it could really be tested from.

With the X-33 there are a number of options. The options include the Edwards Air Force Base, the White Sands Test Facility, and of course the Cape Kennedy—Cape Canaveral Air Force Station.

We will wait for recommendations from our industrial partners before we address that issue, though.

Col. PAYTON. May I talk to that?

Dr. MANSFIELD. Yes. Col. Payton.

Col. PAYTON. We are working with the Air Force. In fact, we have asked the Air Force to be the lead government agency working with the industry teams to identify which ranges, which test ranges, can help us accomplish which test objectives.

Additionally, the environmental impact of this bird as it flies in these different ranges. No matter which range we end up using, though, we have a test philosophy of something that we brought from the airplane world which is incremental expansion of the flight envelope.

On the X-33, the very first flights will be very short range. So then we will expand the flight envelope on each flight and test a broader envelope on each flight. That is how you build confidence in the bird and you build confidence in the technology that is inside that bird. That is what lends you the confidence that says we will not have the same kind of growing pains on the first commercial launch like we have seen recently with the CONESTOGA and other commercial launchers.

So it is this incremental expansion of the flight envelope that lets you build confidence in the underlying components of the bird.

Mr. DAVE WELDON [FLA]. Well shifting to basically money issues, which seems to be the center of discussion here this morning, and appropriately so in a setting of a Nation that has a $5 trillion debt and is spending more on interest on its debt in 1996 than almost—almost more than what we are spending on national defense—and indeed I feel that balancing our budget is going to be crucial for our ability to actually fully see a vehicle deployed.

If we do not have our books on the way to being balanced, you are never going to get $6- $8- $9 billion, the figures that are being thrown around here.

So there may be some Members who may criticize us for some of the budgetary measures that we have taken, but I can say honestly that if you do not make those decisions now, even though they are painful, there are going to be no dollars, in my opinion. There is going to be no way to justify those kinds of expenses in the future.

So I think we all have a real vested interest in doing what we are doing, even though it is somewhat painful.

I heard you list all your criteria—

[The buzzer sounds.]

Mr. SENSENBRENNER. The gentleman's time has expired.

Mr. STOCKMAN: —and just to close, I would list number one, two, and three as cost reduction, cost reduction, cost reduction.

I mean, whether you are single-stage, or whether you have got this type of design or that type of design, I mean if it is too expensive, it is not going to work and it is not going to fly.

Mr. SENSENBRENNER. And with that happy note, the gentleman from Indiana, Mr. Roemer, is recognized.

Mr. ROEMER. Thank you, Mr. Chairman.

Mr. Chairman, I think this is a very important hearing because we are discussing the health of the U.S. launch industry and the competitiveness of the U.S. launch industry.

Certainly when Chairman Sensenbrenner said that every member of this subcommittee is supportive of those two efforts, I could not agree with him more.

We want to see these kinds of programs succeed, and we want to do it in a cost-efficient manner. I could not help, in reading one of the Hill publications this morning, noticing the picture of the DC-X from McDonnell Douglas on the back page there.

That kind of technology is creative; it is exciting. I think it does provide some windows for opportunity for us to get into some new areas in the future.

Dr. Williamson argued pretty forcefully in his testimony that there is not enough of a market out there right now.

Do you see that changing?

How might you respond to his testimony in terms of this Reusable Launch Vehicle?

Mr. ORDAHL. Well, I think I generally agree with that. If you look at the near term—and that is why we sitting here I think unified generally agree that we have to develop some type of a partnership between industry and government to get this program to a point where it really will be successful.

Now I say that in the near-term sense. It will have to be a transition from our current launches onto this new launch vehicle, and then hopefully if we are very successful in driving down the cost, and then of course can open new markets, because surely we are at the beginning of the space age not at the end of the space age. That is our belief. Otherwise, we would not be here talking about this, I do not think.

So, assuming that is true, if we can get the costs down, then new markets will open. Some of those were even mentioned I think earlier. From that, then, more benefits will come.

But I think in order to get it jump-started we have got to solve the business of working together somehow to make it successful, and the government market is a big part of this.

As far as cost-effectiveness is concerned, I think the numbers $2.5 billion on the Shuttle, and $1.5 billion annually in DoD, when you add those that is $4 billion, and I am sure there is more. Then when you get into the commercial sector—so there is lots of money being spent on things every year. So how can we transition that into a more cost-effective way to spend it on other things?

Mr. ROEMER. Dr. Mansfield, would you say that this is, as Mr. Brown articulated to you, that you are getting beat over the head a number of times, that this is a very, very high priority for NASA to move forward in this area?

Dr. MANSFIELD. It is. It is Mr. Goldin's number one priority for the agency, and he has continued to tell us that. If he had any money added to the agency at all at any time, he would put it on this.

Mr. ROEMER. Let me ask you a follow-up to Chairman Sensenbrenner and Mr. Brown's questions. This entails both the monetary concern and a judgment concern for evaluating the progress of the X-33 program.

In your testimony you stated that, and I will quote, "there is no single correct projection of funding to achieve the goals of the RLV program," yet, one of the criteria developed by NASA and OMB to evaluate whether the proceed to phase III and the full-scale development states, and I will quote again, "the X-33 and the X-34 programs will have demonstrated by meeting their respective program goals within a fixed government budget," and it goes on. Unquote.

How do we judge whether we are meeting the criteria if the amount of the funding remains vague? What kind of things are you going to use then in your judgment in addition to this?

Dr. MANSFIELD. Well, sir, we absolutely have to pin down the amount of the funding. I cannot guarantee a result if the amount of funding is going to be vague in the outyears.

We can commit to it if we have a good promise of funding in the outyears over the life of the X-33 program. The risk is that we would guarantee flight by a certain date, March 1, 1999, is the date that we would want to aim for. The risk is that we would aim for that and then have the funding disappear or get reduced in the outyears and not be able to deliver.

That is the old way of doing business, and we cannot have that happen.

Mr. Goldin is not going to let that happen. He is going to make sure that we deliver on our promises. But you are right, there is vagueness because of our perception—Col. Payton's perception and my perception—that this is a risky program, that there are no reserves; that the original budget that went out and was presented to you is one that can succeed but, if anything happens, it will cost more and—

Mr. ROEMER. What is the biggest risk to this program, then? You said the vagueness in the budget is the lack of—

Dr. MANSFIELD. The biggest one is we are going to pick one concept in the summer of 1996. In the past when the government has dealt with the issue of new kinds of technology, we tried several different things, and that is what the X airplanes were for.

Our current budget only allows one tail number of one design. That is very risky. So I would say the riskiest thing is that we are selecting down to one concept.

The second riskiest thing is that we are relying on one vehicle, and one vehicle only.

Mr. ROEMER. Thank you.

Mr. SENSENBRENNER. The gentleman's time has expired.

The gentleman from Pennsylvania, Mr. Walker.

Chairman WALKER. I thank you, Mr. Sensenbrenner.

Let me preface my questions here for a moment to say that I believe this program is one of the fundamental programs we have to have for the future if we are going to engage in commercial space in the next century.

I am very enthusiastic about the direction that you are going.

I also say that as someone, though, who felt as though he got burned pretty badly on the NASP program. He got burned by NASA and by the industry when we spent hundreds of millions of dollars and did not ever create a vehicle.

We created a lot of great drawings and some pretty pictures that were brought before the committee, but we never flew a vehicle.

I think it is extremely important in this program that we make certain that funding profiles and everything else fit with the ability to fly a vehicle for real.

I know that is what Dan Goldin wants to do, and I am encouraged that Gary Payton is down at the NASA now because he has proven that he is willing to go out and fly vehicles. I think that is extremely important.

But given those criteria, let me ask just a couple of questions:

NASA has told us at this committee that the reason for doing the X-34 program was because it could do precursor technology to X-33 and it would benefit us.

Now I am given to understand that the X-34 program is in real trouble and may end up not going forward. If that happens, does that have a detrimental impact on X-33?

Dr. MANSFIELD. Sir, if I could take that, Chairman Walker?

Chairman WALKER. Sure.

Dr. MANSFIELD. The purpose of the X-34 program initially was to let NASA fly small satellites in an affordable fashion. We needed $5 million to $7 million a launch because the satellites we were building were going to be $50 million satellites. We could not afford Deltas anymore, $50 million Deltas, if that was the case.

So our initial commitment to this program was based on the need to launch those small satellites.

Nevertheless, the proposals that came in generally included a Reusable Launch Vehicle. The current one, the Orbital-Rockwell Partnership involves a partly reusable vehicle, the X-34, which flies up and then launches in the upper stages to launch the satellites, and aims at the $5- to $7 million performance.

Now what that could give us would be evidence that Reusable Launch Vehicles could be operated regularly and for predictable

and affordable costs. It would not do that until about the year 2000, which is after we need to make the decision about then—but it definitely would contribute to industry's confidence in deciding to put money into this full-scale reusable launch vehicle if the X-34 demonstrated its reusability.

But to summarize again, we initially went after this program because we needed to launch satellites, but we are perfectly aware of the importance—of the utility of the technical information we get from it, and the operational information we get from it.

We need that program to succeed. If we make any changes in that program, ever, it will be because we have to have the program succeed.

Chairman WALKER. But if that program does not succeed, does that mean that that indicates a difficulty for the X-33?

Dr. MANSFIELD. For the X-33? I don't believe it would, sir. The X-33——

Chairman WALKER. There is not a linkage in NASA's mind at this moment between the success of the X-34 and the potential success of X-33?

Dr. MANSFIELD. Gary, would you like to—Col. Payton.

Col. PAYTON. We have a number of flight test articles that the total RLV program is building. One of them is a hydrogen-oxygen rocket that fits in between the tails of the SR-71.

The DC-XA we have already heard about today.

So there is a large number of flight test operations throughout the life of the program.

The demise, or the flight test failure, or the termination of any single one of those is not detrimental to the total data base, the total suite of information we need to make the 1999 decisions. So the loss, either through flight test or through programmatic reasons, of any given single program does really jeopardize the total suite of information that we will be gathering between now and 1999.

Chairman WALKER. Well, I appreciate the information that you have given us. I must say that that does differ with previous testimony that we have had here, and it also differs with what the White House told us originally on the X-34.

I mean, a portion of what we were told earlier was that X-34 was going to be a necessary part in doing X-33.

Now it seems to me I am hearing something very, very different from the panel here today. I think that does give this committee a little bit of pause.

Dr. MANSFIELD. If I could——

Mr. SENSENBRENNER. The gentleman's time has expired.

The gentleman from——

Chairman WALKER. Well, could Dr. Mansfield at least respond to that?

Mr. SENSENBRENNER. Surely.

Dr. MANSFIELD. If I could, with your permission, Mr. Chairman?

Mr. SENSENBRENNER. Surely.

Dr. MANSFIELD. The X-33 program will begin its full-scale development next summer, and it will fly by March 1999. The X-34 program, which is in design now, is planned to begin its test in 1997. The tests will not have accomplished anything in time to influence

X-33 design. What they will influence is the full-scale Reusable Launch Vehicle decision, because they will give industry data that Reusable Launch Vehicles are—can be operated for predictable costs.

Of course that technical data is going to be useful, but not for the X-33 program.

Mr. SENSENBRENNER. Just to complete the record, Mr. Goldin sent a letter with attachments to me dated February 24th, 1995, in response to written questions following his testimony at the posture hearing that was held.

Question 9 says. I appreciate your commitment that the X-33 and X-34 program funds will be fenced so that the X-34 cannot take over the X-33 funding scheme as some have proposed. Given that the X-33 is aimed at radical cost reduction and the X-34 is not, does that make sense to fund X-34 at all?

Answer 9, in part. Finally, the X-34 is a necessary early opportunity to understand the operational costs of an RLV. These lessons learned will feed directly into the X-33 and any subsequent RLV programs and are a critical component of the program. Unquote.

That was the attachment of the letter that Administrator Goldin sent to me in February of this year.

I would appreciate, Mr. Mansfield, and I think you are going to have to get back to home plate on this, to explain the difference between what Mr. Goldin told us in February in his written response that is already in the public record and what you have said now.

Without objection from the committee members, I will place that response into the record before this goes to the GPO.

Dr. MANSFIELD. Of course, sir.

[The following response was received for the record:]

As I indicated previously, the DC-XA and X-34 programs are the vehicles through which we are transferring into NASA the program management experience developed by the BMDO in the course of the DC-X program. In addition, the X-34 will offer early flight testing of a number of technologies developed subsequent to the Shuttle and not yet flight tested. Finally, the X-34 is an early opportunity to understand the operational costs of an RLV with much higher performance than DC-XA. These management and operational "lessons learned" will feed directly into X-33 operations and any subsequent RLV program. Thus in the unlikely event of cancellation of the X-34 program, these "lessons learned" would not be available for the X-33 or subsequent programs.

As you are aware, we at NASA and our industry partners in the X-34 program have been refining our relationship. While the NASA RLV team is dedicated to the principle of industry leadership, we have also recognized—as partners—our responsibility to protect the Government's investment, and to assure that our goals for that program are given equal hearing. We believe that working with our partners to develop a clear understanding of the meaning of an industry-led partnership has resulted in a very valuable management "lesson learned" about such partnerships which we intend to immediately apply to the X-33 Phase II effort. Thus while NASA cannot say categorically that it would continue with the X-33 program regardless of developments in the X-34 effort, we are not presently aware of any issues in the X-34 program which would affect our going ahead with the X-33 effort.

Dr. MANSFIELD. All I offer now—and we will provide as precise an answer as we can—all I offer now is that the X-33 design will be finished, and the X-33 will be being built before the X-34 flies. So it really has no impact on the design of it.

But the comment that Mr. Goldin was answering undoubtedly was discussing the program as a whole where the results of both programs were needed.

Mr. SENSENBRENNER. But again the OMB criteria that has been given to us by the Office of Management and Budget, which Mr. Roemer alluded to, that their decision to fund Phase II of X-33 was dependent upon an X-34.

My feeling is that we are going beyond that. If X-33 is a precondition to X-33, according both to OMB and to Mr. Goldin's letter to me, we might be having a misconnect.

Dr. MANSFIELD. I believe I understand the misconnection now. It is not a technical prerequisite for continuing with the X-33 program because the X-33 program as I said will be in construction already.

However, as a matter of fiscal and programmatic discipline, the OMB has insisted that we live under certain criteria. They will not release the money to us to continue with the X-33 program without certain milestones being achieved.

The X-34 is one of those milestones. We have to do certain things in the X-34 program in order to be allowed to proceed. That is a fiscal and managerial control. It is not a technical—it does not indicate that the technology is required to succeed with the X-33.

Mr. SENSENBRENNER. We will await an answer on this point.

Mr. CRAMER. Would the Chairman yield on that point?

Mr. SENSENBRENNER. We have a vote on. Mr. Cramer, you are next up to be recognized.

Mr. CRAMER. If I could make a couple of points fairly quickly, then, I will not even need to be next.

Mr. SENSENBRENNER. The gentleman from Alabama is recognized, but the Chair intends to recess the subcommittee shortly after the second bell rings.

Mr. CRAMER. Yes, sir.

Regarding the X-34 program, certainly you can tell from our interest here today that if a decision has been made to cancel that program, then that decision needs to be deferred, in my opinion, until we move on with the X-33, or until we at least clarify the linkages between X-34 and X-33.

Would you care to comment about that?

Dr. MANSFIELD. We are watching the X-34 program very carefully. We have met with the contractor team yesterday. We are going to make recommendations to Mr. Goldin this week. We do not have anything to announce at this time.

We will obviously consult with everybody before we make any announcements at all.

I do not mean to indicate by this that the ax is on the backswing; that we think this program is in chaos or anything like that.

It is just that we insist on success with that program. The success for us is, we have to be able to launch small satellites regularly or NASA is out of the science business.

Our entire scientific program depends on our being able to launch small satellites for $5- to $7 million. If we cannot do that, we cannot deliver on the promise of space science.

That is what we have got to have. That would be—the only reason for any change in that program is if we are convinced that there is danger that that is happening.

We are not going to do anything lightly, or we are not going to do anything rashly.

Mr. CRAMER. Could I get you to come back to X-33 since time is very precious here and I do not want to keep members beyond the next bell?

What are some of the possible outcomes of the X-33 program?

Dr. MANSFIELD. There is one overwhelming and single outcome. A successful test program of a vehicle that demonstrates the six criteria that I mentioned. In particular, it has to demonstrate that you can build a full-scale vehicle and it can be affordably operated.

Our criteria will do that. So that is the single most important outcome, is that it operate through a test program and it demonstrates our six criteria for success. Two of them are technical and four of them are programmatic.

Those criteria are the ones that would allow us a successful system to be operated.

Mr. CRAMER. All right.

I want to express my support for the RLV program. As I say, I think it is crucial that this country reduce the cost of our space transportation.

Having said that, Mr. Chairman, I will yield back my time.

Ms. JOHNSON. Mr. Chairman, I have a parliamentary inquiry.

Mr. SENSENBRENNER. The gentlelady will state it.

Ms. JOHNSON. Thank you, Mr. Chairman, and I will not take long. It is an important issue to me, and I will be on the House Floor on a debate that might possibly be coming up very, very shortly.

I would ask whether we would be allowed to submit questions to these gentlemen? Some of these are not government witnesses, I realize that. I would appreciate very much answers involving subcontracting costs and minority contractors.

Mr. SENSENBRENNER. Absolutely. And I would request that witnesses who do receive written questions from the subcommittee and its members please respond within about two weeks so we can get the hearing record off to the Government Printing Office.

Ms. JOHNSON. Mr. Chairman, I thank you very much. It is an important issue and one that I support.

Thank you.

Mr. SENSENBRENNER. The subcommittee is in recess until shortly after this vote is completed, and then we will continue.

So I would encourage members who have got further questions to be back promptly.

The subcommittee is in recess.

[Recess.]

Mr. SENSENBRENNER. Let me state that I appreciate the indulgence of both the witnesses and the audience that we had to go over and vote.

I do not know how many of the people who were waiting to ask questions will come back, but I have a couple of questions of Dr. Mansfield and Colonel Payton basically to close the loop in where we left off before the recess.

From what you have said, Mr. Mansfield, it appears that if the X-34 is cancelled, contrasted to what was stated to us by Mr. Goldin and the quotation that Mr. Roemer used from OMB, we are giving OMB the opportunity to cancel the X-33 because there is no X-34 which was stated by OMB to be a precondition to X-33.

Is this a justified fear of mine?

Dr. MANSFIELD. We have to satisfy the OMB criteria, first.

That is certain.

Mr. SENSENBRENNER. They said you have to have an X-34 and use some of that technology to build the X-33, and so did Mr. Goldin say that in his letter of February 24th to me.

Dr. MANSFIELD. We are not going to make any changes in the program that jeopardizes the X-33 or our ability to launch small payloads.

We realize that those programs are linked. We have presented them to you as links.

We presented the—there is a graphic we have showing the program, the areas of the program versus years, and the arrow from the X-34 joins the X-33 program in the year 2000.

That does not mean that there is not any clear transfer of information before that, of course.

We are going to be as careful as we can, and as responsible as we can not to make any dumb mistakes here.

Mr. SENSENBRENNER. Well, as you know, a lot of the ground rules in this town are set by OMB, not by NASA, and not by Congress, and maybe not even by the President of the United States.

I just do not want problems in X-34 jeopardizing X-33. I would urge you and NASA to think this through, and to think this through very carefully.

Because the place where there is the largest anti-NASA/anti-space program mindset is in OMB.

That is not true just with this Administration; it is within the previous administrations that have been in office during the time that I have been privileged to serve in the Congress.

Col. PAYTON. There is something that is important about all of the criteria that we have negotiated. These are metrics on the program.

Right on the first page of the criteria is the statement that they are, all of the metrics are subject to negotiation and subject to change based on configurations, based on budget appropriations.

So, while—especially for technology program, a technology development and demonstration program, you really want metrics to show progress in the program and to judge progress in the program.

That is the fundamental objective of the criteria document, and that is why we have asked our industry partners to go charge for those metrics and objectives.

Mr. SENSENBRENNER. Well,I think we have probably explored this to the greatest extent that we can today.

Let me say that this subcommittee and this chairman eagerly awaits the written response to the apparent inconsistency of the testimony which we have just discussed.

Thank you.

If there are no further questions, the subcommittee is adjourned. I would like to thank all of the witnesses for presenting some really tremendous testimony.

[Whereupon, at 12:05 p.m., Wednesday, November 1, 1995, the hearing was adjourned.]

[The following material was received for the record:]

Responses to written questions submitted by Chrm. Sensenbrenner resulting from the November 1, 1995, hearing.

QUESTION 1:

The X-33 "Advanced Technology Demonstrator" is not just another X-plane, but is also not just a technology program. How would you compare the X-33 concept with the X-program concept? What are some of the benefits to the typical X-vehicle approach which may be lost under this program concept?

- Explain what the Cooperative Agreements require of industry, versus the performance expected from industry under a traditional program contract?

ANSWER 1:

While certainly different from a "traditional" fully government funded X-Vehicle development and flight program, NASA believes that the differences between the X-33 program and a "traditional" program are a net advantage. Specifically, the focus on an industry-led effort, with industry co-investment, is expected to produce significant cost savings to the government. For example, the Mach 6 capable X-15 vehicle cost about $1 Billion in 1995 dollars to develop, yet via a cooperative agreement similar to the proposed X-33 Cooperative Agreement, the X-34 program will--if successful--deliver a Mach 12-14 capable vehicle at a total government cost of less than $70 million in 1995 dollars. Similarly, a very rough-order-of-magnitude (ROM) estimate would suggest that a "traditional" X-33 program would cost about ten times what the government's commitment to the X-33 is expected to be under a cooperative Agreement.

We are presently unaware of any benefits that would be available under a "traditional" program and not available under the planned X-33 effort.

Since the X-33 Phase II Cooperative Agreement is not yet negotiated, we are only able to address the X-33 Phase I and the X-34 Cooperative Agreements with respect to their requirements. These Cooperative Agreements offer industry leadership (not control) in partnership with the Government. In exchange, the Government limits its risk of program cost growth. By its nature, a partnership, being consensual, requires that all partners agree on the proposed course(s) of action. Thus the Government gives up the ability to specify and direct the program decision making at the detail level, without the agreement of its industry partner(s), except in the case of a decision to withdraw from the partnership altogether.

QUESTION 2:

Is building the X-33 the best way to achieve the risk reduction purpose of the program?

- In terms of the program's areas of emphasis for reducing technology risk, which is considered the most important--reducing the weight of the launcher, or increasing the power of the engine?

- In terms of business risks, which is considered most important--reducing the

manpower required to operate the vehicle, or increasing the safety margins to prevent the loss of the vehicle?

ANSWER 2:

NASA believes that building flight test vehicles is the lowest risk means of achieving the goals of the RLV program; with industry leadership of a cooperative program, we also believe we will achieve the lowest cost program.

Both the dry mass of the vehicle and the ratio of the engine's thrust to its weight are areas where improvement will be required to achieve Single-Stage-To-Orbit (SSTO). Their relative importance and the means of achieving improvements are highly dependent on the specific vehicle design, which has not yet been chosen.

Similarly, the relative importance of reducing operational manpower or increasing safety margins will depend on a series of trades to be made during vehicle design. Operations costs and reliability improvements resulting from increased safety margins will be traded against each other, as well as against development and acquisition costs, to attain the lowest cost over the life of the program. The DC-X has convincingly shown that an automated, low-labor-intensity, reusable launch vehicle is feasible and can reduce operational costs relative to the Space Shuttle. Increasing safety margins improves reliability, which in turn will ultimately result in lower insurance costs per flight. On the other hand, automated systems and increased margins raise development and acquisition costs, offsetting operational and insurance cost savings. The ultimate balance of system capabilities will be determined in upcoming phases of the RLV program.

QUESTION 3:

When you were negotiating the Cooperative Agreements with the X-33 teams, was the level of funding or the funding profile a concern to industry at that time?

- Did the industry teams put any condition on their willingness to invest their own funds in X-33 relative to NASA's increasing funding or changing the funding profile?

- How much investment will be made by private industry in the X-33 program during Phases I and II?

ANSWER 3:

For the Phase I X-33 Cooperative Agreements, industry did not express a concern with respect to the level or profile of funding. Discussions with our partners do indicate that both the level of funding and the funding profile are areas of concern for them with respect to the upcoming Phase II Cooperative Agreement.

None of our partners has placed any conditions with respect to their investment in the Phase I program. As the Phase II Cooperative Agreement Notice (CAN) has not yet been issued, we do not presently know whether any conditions may be forthcoming from industry with respect to that phase of the program.

During Phase I, each of our partners is contributing about two-thirds of the total

funding for the effort. Again, since we have not yet issued the Phase II CAN, we do not know how much industry will be contributing.

QUESTION 4:

The industry has requested a change in the government's funding and/or funding profile.

- Will NASA honor industry's request by requesting increased funding in Fiscal Years 1997 and 1998?

ANSWER 4:

NASA is currently working with the White House to develop our 1997 and out-year budget submittal; while we recognize industry concerns, the RLV program budget is necessarily affected by NASA's overall budget, and the priorities therein.

QUESTION 5:

Assuming no changes in program content--such as building a second copy of the X-33 vehicle--do you believe the level of funding provided by the Cooperative Agreement Notice sufficient for industry to build the X-33 while reducing the technology risks enough to proceed with Phase III?

ANSWER 5:

NASA believes that the level of funding outlined in the Cooperative Agreement Notice is sufficient--assuming industry leadership of the program--to develop a single reusable vehicle of about one-half scale as compared to an SSTO, and capable of reaching sub-orbital velocities sufficient to qualify the thermal protection system for orbital vehicle use. This level of funding does not provide any contingency for vehicle failure during the test program, nor does it provide for alternative technologies to those tested on the flight vehicle.

QUESTION 6:

If Congress agrees to move some of the funds forward from 1998 and 1999 to 1996 and 1997, do you believe industry will be willing to match the increases provided in those years?

ANSWER 6:

No. Front-end funding poses the greatest challenge to industry due to time value of money considerations and greater risks in the early years.

QUESTION 7:

Since industry has never raised private capital for the complete development of a new launch system, how is it that this program will stimulate such an enormous investment?

ANSWER 7:

The Pegasus, Taurus, and TOS vehicles from Orbital Sciences Corporation, as well as the PAMs from McDonnell Douglas Corporation, were all privately financed. While the scale of these investments was much smaller than that anticipated for an RLV (which will require one of the largest private financings in history) it is nonetheless instructive to recognize that private financing of commercial space launch systems has been occurring for more than a decade.

A primary objective of the RLV program is to alleviate, to the extent possible, the business and technical risks which are impediments to the privately financed development of a new reusable launch system. In parallel with the X-33 design, construction and flight test program, the industry team will also develop a comprehensive business plan for Phase III. This business plan will include market analysis, risk assessment, internal rate of return calculations, determination of required government incentives, etc. to form the basis for their investment decisions.

QUESTION 8:

Dr. Williamson, in his testimony, raised the possibility that the EELV program being funded by the Air Force will COMPETE with RLV for government markets.

- Do you agree EELV competes with RLV?

- When does NASA anticipate a choice can or will be made between these competing concepts?

ANSWER 8:

NASA does not view the RLV and EELV as competing programs. The EELV program offers a near-term, interim solution for reducing the high cost of space launch, with a payback before a next-generation launch system will be operational. The RLV, on the other hand, has a longer range focus toward dramatic reduction of launch costs well into the next century. Since these concepts do not compete, we anticipate an orderly transition from EELV to RLV rather than a competition.

QUESTION 9:

The industry witnesses appear to agree that a financial and market issues "Summit" is a necessary next step toward obtaining forward-looking government commitments for use of the RLV in Phase III.

- Does NASA plan to conduct such a Summit, or should Congress conduct this summit?

ANSWER 9:

NASA understands that all the industry partners in the X-33 program believe that some sort of Government commitment to purchase RLV launches will be required prior to full scale development. NASA is exploring the possibility of establishing an informal working group to facilitate the development of workable financial solutions.

This informal working group could include staff representatives from the industry, the Office of Management and Budget, the Congress, the Congressional Budget Office and NASA. NASA will consult with the Committee as this idea is further developed.

QUESTION 10:

What is the relationship between the X-33 and X-34 program? Is proceeding forward with the X-33 program dependent on the success of the X-34 program? What is NASA's justification for the X-34 program?

ANSWER 10:

As NASA has indicated previously, the DC-XA and X-34 programs are the vehicles through which we are transferring into NASA the program management experience developed by the BMDO in the course of the DC-X program. In addition, the X-34 will offer early flight testing of a number of technologies developed subsequent to the Shuttle and not yet flight tested. Finally, the X-34 is an early opportunity to understand the operational costs of an RLV with much higher performance than DC-XA. These management and operational "lessons learned" will feed directly into X-33 operations and any subsequent RLV program. Thus in the unlikely event of cancellation of the X-34 program, these "lessons learned" would not be available for the X-33 or subsequent programs.

As you are aware, we at NASA and our industry partners in the X-34 program have been refining our relationship. While the NASA RLV team is dedicated to the principle of industry leadership, we have also recognized--as partners--our responsibility to protect the Government's investment, and to assure that our goals for that program are given equal hearing. We believe that working with our partners to develop a clear understanding of the meaning of an industry-led partnership has resulted in a very valuable management "lesson learned" about such partnerships which we intend to immediately apply to the X-33 Phase II effort. Thus while NASA cannot say categorically that it would continue with the X-33 program regardless of developments in the X-34 effort, we are not presently aware of any issues in the X-34 program which would affect our going ahead with the X-33 effort.

Responses to written questions submitted by Cong. Roemer resulting from the November 1, 1995, hearing.

QUESTION 1:

Please outline the specific contributions that the following planned contractor activities will make to the X-33 technology verification phase of the RLV program:

- SR-71 test flights of the 1/10 scale Rocketdyne Aerospike engine
- Testing of the DC-XA vehicle
- X-34 testing and technology development
- Shuttle-carried experiments

ANSWER 1:

The RLV program uses a "stepping stone" approach to the flight demonstration of critical technologies. Each subsequent flight demonstration is more integrated, larger, and flies in environments more similar to the next generation RLV - culminating with the X-33.

The SR-71 aerospike experiment is one part of a three part effort to characterize the performance and controllability of an integrated lifting-body vehicle / aerospike engine (the second two thrusts are wind tunnel testing and computational fluid dynamics analysis - CFD). The data developed from the flight testing will establish a database for validating analysis methods and tools (CFD) for use on X-33 system design.

As NASA has indicated previously, the DC-XA and X-34 programs are the vehicles through which we are transferring into NASA the program management experience developed by the BMDO in the course of the DC-X program. In addition, as the first integrated RLV flight demonstrator, the DC-XA will incorporate the following technology components into the quarter-scale system: (1) aluminum-lithium liquid oxygen tank, (2) composite liquid hydrogen tank, (3) composite intertank structure, (4) integrated auxiliary propulsion system including a liquid-to-gas conversion system, and (5) advanced hydrogen leak-detection sensors. Each of these components will be built to technical specifications traceable and scaleable to the X-33/RLV. Testing of the upgraded technology components in flight and natural environments will be used as an early demonstration of system operability. As the second integrated flight system, the X-34 will offer early flight testing of a number of technologies developed subsequent to the Shuttle and not yet flight tested. These include composite structural components and highly automated flight operations. The X-34 is an opportunity to understand the operational costs of an RLV with much higher performance and larger scale than DC-XA; these management and operational "lessons learned" will feed directly into X-33 operations and any subsequent RLV program.

The Shuttle provides a testbed for advanced RLV technology components. As an example, it allows key avionics and thermal protection system technologies to be tested in realistic ground and flight operational environments. The Shuttle will be used to test select components early to build confidence prior to their integrated test on the X-33.

Responses to written questions submitted by Cong. Brown resulting from the November 1, 1995, hearing.

QUESTION 1:

What should be the measure of whether the X-33 program has been a success?

ANSWER 1:

The X-33 will demonstrate critical technologies required for future low cost reusable space transportation systems. The X-33 must demonstrate that these advanced technologies not only meet performance requirements, but are operable and maintainable. The X-33 will be fully successful if enough business, operational, and technical risks are retired in the X-33 program to allow the development of a commercially viable launch system. In any case, the critical technologies demonstrated in the X-33 could be used to upgrade the Shuttle or develop other reusable space launch systems (e.g., multistage). Finally, the program is a success if it demonstrates that an industry led partnership can build and fly a space vehicle within a fixed government funding and fast paced schedule.

QUESTION 2:

If all of the business plans provided by the industrial teams competing for the X-33 program assume government commitments that either cannot be made or cannot be guaranteed at the time the X-33 contract is to be awarded, do you still intend to proceed with the X-33 program?

ANSWER 2:

NASA's X-33 Phase II technology demonstration program (FY 1996 through FY 1999) is focused on developing elements necessary to demonstrate SSTO feasibility and the viability of a next generation reusable launch system. The Phase II decision in FY 1996 will be based on industry proposals which will include options for government commitment for investigation during the X-33 Phase II program. Options for government commitment must be developed and agreed to by the Administration, Congress, and Industry. In the absence of such agreement the next generation launch system is not likely to be developed on a commercial basis.

QUESTION 3:

The NASA Advisory Council's August 1995 letter to Administrator Goldin expressed a number of concerns about the current direction of the Reusable Launch Vehicle program. In particular, they have expressed concern that the sole focus on Single-Stage-to-Orbit (SSTO) does not leave NASA with credible alternatives if the SSTO approach proves to be technically feasible or operationally unacceptable. The NAC recommends that some of the resources be devoted to exploring non-SSTO approaches and technologies.

a. Has NASA responded to the NAC's letter? If so, what was the response? If not, when to you intend to respond?

ANSWER 3a:

NASA has not responded to date. We intend to do so in the near future.

QUESTION 3b:

In response to the argument that no parallel non-SSTO design activity is required since SSTO technologies are applicable to non-SSTO approaches, members of the NAC may have countered that the use of advanced technologies required for an SSTO may be neither necessary nor appropriate for less technically challenging alternatives such as Two-Stage-to-Orbit. How would you respond?

ANSWER 3b:

NASA believes that, if achievable, single-stage systems will be more economical than two-stage systems. Moreover, analysis accomplished thus far suggests that a next generation RLV, whether single- or multi-stage, will offer lower life-cycle costs if it utilizes the advanced technologies to be demonstrated by the RLV program instead of current technology.

Responses to written questions submitted by Cong. Rohrabacher resulting from the November 1, 1995, hearing.

QUESTION 1:

According to your testimony, NASA's fiscal year 1996 budget submission for the X-33 program was prepared before you came on the job. Who prepared the budget? Was there any consideration of a proper X-project-type budget profile, and who decided to submit a procurement-type budget?

ANSWER 1:

The original budget request for FY 96 was prepared by Mr. Jack Lee, who at the time was a Special Assistant to the Administrator. The budget profile that was submitted met the program goals, as they were understood at the time.
Mr. Gary Payton was subsequently hired to manage the X-33 program and his recent Air Force experience managing many types of fast track hardware programs led him to conclude that program risk would be reduced if funding were rephased.

QUESTION 2:

NASA officials have told me and my staff that while the Fiscal Year 1996 X-33 budget had been seen as too small within NASA earlier this year, the problem was "fixed" by NASA Comptroller Mal Peterson. How big was the problem, and exactly how did Mr. Peterson "fix" the problem?

ANSWER 2:

Concern over the level of FY 1996 funding arose primarily because of some industry comments on the compression of the Phase II schedule. NASA does not recommend additional funds at this time, however, the resultant need to get a "fast start" in the remaining months of FY 1996, following an affirmative July 1996 decision to proceed, could require additional FY 1996 funds. The Comptroller's position was that the Agency could and would request an internal reprogramming of funds next summer if the additional funds would materially aid in schedule accomplishment. This solution is available to the Administrator, in consultation with the Administration and Congress, through the operating plan process.

QUESTION 3:

What level of industry financial participation is expected during Phase II by the winning X-33 bidder(s)? (Please express in actual dollars terms and as a fraction of the total X-33 research, development and testing costs).

ANSWER 3:

NASA has not made a final decision whether to include minimum cost sharing requirements in the Phase II Cooperative Agreement Notice (CAN); NASA cooperative agreement policy requires "substantial" cost sharing by industry, but the RLV technology program is focused on outputs, as reflected in the NASA/OMB/OSTP decision criteria, not inputs. The X-33 industry partners are

free to propose any cost sharing arrangement that will allow their X-33 program to meet overall technical and programmatic objectives, and may also propose alternative funding splits between the ground and flight test elements from those presented in the X-33 CAN. NASA believes that the Agency funding in the baseline program is adequate to meet current program objectives, although with some risks; there are no funds for alternative technologies outside the winner's X-33 and RLV concept, and there is no contingency for loss of a vehicle during flight tests. Industry proposals for Phase II will be evaluated on how well they address the program's objectives and minimize risks, not on the amount of their own resources they are willing to commit.

QUESTION 4:

How has your experience with the X-34 program, especially recent events, influenced your thinking about the use of Cooperative Agreements as an effective instrument for purchasing advanced technology demonstrations?

ANSWER 4:

The recent issues related to the X-34 program were schedule driven and are not unique to a Cooperative Agreement. There are significant benefits to be gained from a Cooperative Agreement: 1) fixed cash contribution from NASA; 2) fixed percentage of Government contribution to the total effort at any given time (X-34); 3) NASA payments based on milestone accomplishment, not cost accrual. These benefits provide NASA management tools not available in a standard contract environment. As a result, NASA's desire to use the Cooperative Agreement on the X-33 is strengthened.

QUESTION 5:

Could the use of "other transactions" authority, as described by ARPA General Counsel Rick Dunn at the November 8th full Science Committee hearing on NASA purchasing, be more effective for achieving NASA's goals in the X-33 program?

ANSWER 5:

Cooperative Agreements are the instrument NASA has determined appropriate for cooperative efforts where funding is provided. "Other transactions" authority in NASA would be a Space Act Agreement, where industry funding is not provided and hence is not applicable in this case. NASA used Cooperative Agreements in the ARPA Technology Reinvestment Program.

QUESTION 6:

What are, and are not, the goals of the X-33 program?

ANSWER 6:

The X-33 program will implement the National Space Transportation Policy (NSTC-4), specifically Section III, paragraph 2(a): "The objective of NASA's technology development and demonstration effort is to support government and private sector decisions by the end of this decade on development of an operational next-

generation reusable launch system." The X- 33 must adequately demonstrate the key design and "aircraft like" operational aspects of a next-generation RLV rocket system so as to reduce the business and technical risks which enable the private sector to develop a commercially viable launch system. The X-33 is a proof-of-concept demonstrator and is not an operational launch vehicle or shuttle replacement.

Responses to written questions submitted by Cong. Hall resulting from the November 1, 1995, hearing.

QUESTION 1:

NASA and OMB have developed a set of criteria that are to be used to decide in mid-1996 whether or not to proceed with Phase II of the X-33 program.

a. What would you recommend be done if only some of the decision criteria have been satisfied by mid-1996?

ANSWER 1a:

NASA intends to meet all of the criteria agreed to by NASA, OMB and OSTP in the Reusable Launch Vehicle Technology Program Criteria Document. It should be noted, however, that the document states on page 4 that "the RLV design and operations target requirements provided in this document do not represent independent pass/fail criteria and should be assessed in the context of overall systems analysis. Achievement of the required advancement in each area will be assessed with respect to its effect on the total system's ability to perform". In the event that a criterion is not met, NASA will rely on independent assessments of the NASA Advisory Council and non-advocate review panels regarding the impact to overall program goals prior to formulating recommendations to OMB. These committees will provide recommendations to the NASA Administrator prior to a mid-summer decision as to whether all of the Phase II criteria have been satisfied and whether NASA should proceed with the program. The NASA Administrator will make his final assessment and provide recommendations to OMB and OSTP.

QUESTION 1b:

Under what conditions, if any, would you recommend an extension of Phase I and a delay in the initiation of Phase II?

ANSWER 1b:

The SSTO technologies currently under development by the X-33 industry partners are showing significant promise toward meeting the overall objectives of the RLV program. In the unlikely event that these technologies do not mature adequately prior to the mid-1996 decision, NASA could recommend a delay in the initiation of Phase II. This decision would require support from our industry partners and recommendations from the NASA Advisory Council and Non-Advocate Review Panel for an extension of Phase I. In this event or in the event of insufficient budget resources, NASA would be required to rebaseline the program and assess funding and schedule requirements. NASA would also coordinate with the Administration and appropriate members of Congress prior to proceeding with this recommendation.

QUESTION 1c:

Under what conditions, if any, would you be prepared to recommend the termination of the X-33 program at the end of Phase I?

ANSWER 1c:

NASA believes that adequate progress will be achieved in the RLV technology program and the NASA/Industry partnership will be ready to proceed into Phase II in mid-1996. Considering the promise of the emerging SSTO technologies, there are no current conditions which would suggest program termination. The Reusable Launch Vehicle Technology program is an high priority program, and is important for meeting NASA's long term objectives.

QUESTION 2:

With respect to cost sharing by industry, page A-8 of the Cooperative Agreement Notice for the X-33 program states that NASA, "reserves the right to specify minimum cost sharing requirements for Phases II and III."

a. Does NASA intend to establish such minimum requirements, and if so, what are they? If not, why not?

ANSWER 2a:

NASA has not made a final decision whether to include minimum cost sharing requirements in the Phase II Cooperative Agreement Notice (CAN); NASA cooperative agreement policy requires "substantial" cost sharing by industry, but the RLV technology program is focused on outputs, as reflected in the NASA/OMB/OSTP decision criteria, not inputs. The X-33 industry partners are free to propose any cost sharing arrangement that will allow their X-33 program to meet overall technical and programmatic objectives, and may also propose alternative funding splits between the ground and flight test elements from those presented in the X-33 CAN. NASA believes that the Agency funding in the baseline program is adequate to meet current program objectives, although with some risks; there are no funds for alternative technologies outside the winner's X-33 and RLV concept, and there is no contingency for loss of a vehicle during flight tests. Industry proposals for Phase II will be evaluated on how well they address the program's objectives and minimize risks, not on the amount of their own resources they are willing to commit.

QUESTION 2b:

What factors will you assess in determining what constitutes an appropriate level of cost sharing by industry in Phase II of the X-33 program?

ANSWER 2b:

Assessments of industry cost sharing proposals will be performed during the source evaluation process. The appropriateness of industry cost sharing contributions will be based on the unique requirements of the proposals and cannot be determined specifically at this time. The assessments will, in general, be based on factors associated with the technical and economic risks in meeting overall program objectives.

Additional Questions for Mr. Robert Minor
Submitted by the Hon. F. James Sensenbrenner, Jr.

1. *Explain what the Cooperative Agreements require of industry, versus the performance expected from industry under a traditional program contract?*

In the Cooperative Agreements we have with the NASA, industry and government act in a partnership to meet jointly agreed to objectives and goals, whereas a traditional contract often results in an adversarial relationship, with rigid detailed specifications and statements of work imposed on the contractor. Other NASA Cooperative Agreement and traditional contract differences are listed below:

NASA Cooperative Agreement	Traditional Contract
• Industry/government partnership	• Adversarial relationship
• Jointly agreed to objectives/goals and scope	• Government specified requirements and Statement of Work.
• Co-investment required.	• No co-investment required (although possible)
• Minimum oversight and reporting	• Full FAR compliant contract oversight and reporting
• Industry buys government services and products	• Government buys industry services and products
• Industry retains intellectual property rights (Gov't has royalty free license)	• Government retains intellectual property rights
• Mutually agreed milestones and payment schedules	• Government sets milestones and payments
• Either side can terminate at convenience -- no termination liability	• Government termination at convenience, negotiable termination liability

- *From one point of view, the sole purpose of the X-33 program is to provide technology risk reduction to industry. To what extent does that overriding purpose conflict with the programmatic goal of fabricating the X-33 vehicle?*

The overriding purpose of technology risk reduction is not in conflict with the programmatic goal of fabricating an X-33 vehicle. One of the key risk reducing "technologies" is the integration of various technologies, which can be best achieved by the production and flight of the X-33 research vehicle. This risk reduction is maximized when the design, technologies, and operational concept of the X-33 are closely similar to and highly traceable to the final RLV. We believe that a properly structured Phase II risk reduction program includes a balance of ground technologies and the X-33 flight test program because the technology interaction and hands-on system operations experience contribute significantly to the reduction of business, operations, and technical risk.

2. *Is building the X-33 the best way to achieve the risk reduction purpose of this program?*

Yes, we believe that building the X-33 is the best way to achieve RLV risk reduction because it is the centerpiece of an integrated program, which also includes ground development and testing of main engines and other supporting technologies.

- *In terms of the program's areas of emphasis for reducing technology risk, which is considered the most important - reducing the weight of the launcher, or increasing the power of the engine?*

Reducing vehicle weight is more important for technology risk reduction than increasing rocket engine power (thrust level).

From an integrated system point of view, the two choices offered are really two sides of the same issue: if we reduce the vehicle weight, we can reduce the engine thrust level; if we increase the engine thrust level (and hence, its weight), the vehicle weight and size necessarily increase. The singular technical issue is propellant mass fraction. This mass fraction is the ratio of usable launch propellant to vehicle gross lift-off weight. For an SSTO, this ratio needs to be ~0.89 or greater. The remaining 11% includes structure, engines, subsystems, payload, residual propellants and ullage, and propellants reserved for later mission stages. The desired mass fraction becomes even higher as we strive to provide increased margins for safety or performance to meet operability goals.

If we focus on just the engine, then the figures of merit are: thrust/weight ratio and specific impulse. The existing SSME, with a vacuum specific impulse of around 450 seconds, is close to the theoretical maximum for a liquid oxygen/liquid hydrogen engine. This level of combustion efficiency is fully adequate for a SSTO RLV. However, to meet the required system level mass fraction, engine thrust/weight ratio must be improved by reducing component weights while maintaining or improving reliability. The Block II SSME sea level thrust/weight ratio is about 48:1 while the value for an SSTO should be at least 70:1. Therefore, the engine issue is the same as the structure or other subsystems--reduce weight while maintaining performance and increasing operability. Any weight not saved in the engines has to be saved elsewhere in the system.

- *In terms of reducing business risks, which is considered most important - reducing manpower required to operate the vehicle, or increasing safety margins to prevent the loss of the vehicle?*

Increasing RLV safety margins to prevent the loss of a vehicle provides greater business risk reduction than reducing operational manpower. Business risk includes the cost of unreliability, which can be roughly defined as vehicle replacement cost divided by the number of flights between losses. RLV's replacement cost is projected to be on the order of $1000 M and operating manpower is estimated to be about $1 M per flight. Therefore, a 10% reduction in vehicle loss rate, from 1 in 100 to 1 in 110, results in savings on the order of $1 M per flight while a 10% reduction in turnaround manpower decreases cost less than $100 K per flight. Even if indirect manpower costs are added, which may triple the turnaround manpower costs, it is still better to increase vehicle safety margins than reduce turnaround manpower. Additional factors which increase the importance of reducing vehicle loss rate over reduced operating manpower include, but are not limited to: lost revenues from flight disruption after loss of a vehicle, lost opportunity costs, and increased insurance premiums.

3. *In January, NASA issued the Cooperative Agreement Notice to industry to which your company responded. At that time, NASA told you how much funding it would request from Congress through Phases 1 and 2 of the X-33 program.*

- *Why did your company enter into a Cooperative Agreement with the government, knowing of the funding profile, and yet cognizant it was not the correct funding profile?*

Rockwell understood the funding profiles presented in the Cooperative Agreement were for planning purposes only and believed they were negotiable for each Phase. The purpose of Phase I is to define an RLV, its requisite X-33 vehicle, its flight test program, and other supporting ground test and demonstration programs (including main engine development and test) required to reduce RLV risk. The funding profile we provided at the 1 November 1995 hearing was based upon our current baseline, comprising a scaled X-33 vehicle, a healthy parallel engine development program, a focused flight test program, and additional supporting ground technology demonstrations. We are continuing to evolve and refine these estimates as we gain further definition of the details of the Phase II program. It is our intention to present a final Phase II funding profile for our program in our upcoming proposal.

- *Did your company discuss changing the funding profile for the X-33 program with NASA prior to signing the Cooperative Agreements?*

No, we did not discuss with NASA the possibility of changing the funding profile prior to signing the Phase I Cooperative Agreement.

4. *Is the* total *of NASA's X-33 funding - about $1 billion through Fiscal Year 1999 - enough to achieve the risk reduction goals of this program?*

Rockwell believes that NASA's X-33 planned funding will reduce the technical risk of this program sufficiently to meet the program's decision criteria and make a FY-99 decision to develop a full scale RLV. Because this is a high risk program with a demanding schedule, changes in the current profile are needed to provide assurance that we can meet the expected flight schedule. Additional funding would further reduce that risk and the cost of Phase III. Therefore, we recommended three adjustments to the current plan for your consideration in our original testimony. They are: accelerate the current funding profile, include a second flight vehicle as a back-up, and add back-up technology funding.

- *If Congress agrees to move some of the funds forward from 1998 and 1999 to 1996 and 1997, is Rockwell willing to match government's increases in those years?*

Moving funds forward from 1998 and 1999 to 1996 and 1997 is a positive step for the health of the RLV program. We cannot commit today to a specific increase in industry co-investment funds. We are developing our proposal options for submission is May 1996. Our ability to commit will be dependent upon our ability to project a return on investment for shareholders and investors.

Rockwell's timing and level of co-investments for Phase II is a function of several variables. These include the commitment of the US government to complete the Phase II program, the ability of industry to work with NASA on direction of the program to achieve maximum technical risk reduction without threat of NASA withdrawal, the ability of the US government to commit to future usage of the system, and our internal assessment of whether an increased investment in this program is justified in comparison to other opportunities. The bottom line for an increased industry investment is that we have to be able to justify to our shareholders and investors that an increased RLV investment offers a better return than other opportunities. An increase in the government funding in 1997 and 1998 is a very positive signal about the program, and that the government is serious about achieving RLV program goals.

5. *Since industry has never raised private capital for the complete development of a new launch system, how is it that this program will stimulate such an enormous investment?*

Our initial analysis of the business potential of this new launch system is significant, such that we believe a rather large investment can be justified, if the business deal is structured properly.

The stimulus for the required RLV investment is the potential payoff after we get beyond the investment payback hurdle. There are four key reasons we believe it is possible to do this now, even though it has not been done in the past: 1) commercial space transportation is a new industry; 2) there has been a change in the government-business environment relative to space; 3) new technologies make RLV possible; and 4) the amount of investment does not appear to be excessive with proper risk structure.

Commercial space transportation is a relatively new industry, as is much of the commercial space industry. The first commercial products from space are fairly new, and concentrated primarily into a single area --space based telecommunications. But the overall commercial space industry is growing rapidly, as are their requirements for space transportation. The lack of a track record for private investment for a new transportation system is primarily an artifact of the limited number of cases, rather than a lack of sources of investment. We note significant recent private investments for space transportation systems and upgrades including the Delta III, the Atlas IIAR, and the Pegasus.

Furthermore, there has been a change in the environment surrounding government space transportation services. The market environment has changed dramatically in the past decade, and commercial space transportation services can be applied to the governments space transportation markets. Since the government is expected to be the largest single user of such a space transportation system in the near term, this change in environment is significant.

At the same time, new technologies and the hard-won operational experience with reusable launch systems has provided a base from which we can extrapolate a new generation of fully-reusable space transportation systems offering radically lower costs and simpler means to get customers into space. If we can prove out these technologies and put such a system together, there is great potential in the marketplace, and potentially, a breakthrough for new markets.

Commercial venture investments that require billions of dollars are not uncommon in business, and a search of recent financial news can reveal numerous commercial investments capitalized by private industry for billions of dollars. So the financing is there, if the deal can be properly structured. A most important issue in the financing options is to find a way to provide payback of the development investment in a reasonable time frame and still offer low enough launch service prices to attract users.

6. *As you look ahead to Phase III, the government can work with you in at least two ways:*

> ***It can become your partner, and make an equity investment with your company in the development of the operational system. With that, of course, it would expect to enjoy a return on its investment, paid in the form of discounts on the launches it buys. . .***
>
> ***. . .Or, it can stay out of your hair, be a good customer with its large demand for launch services, and pay its bills at market rates, on time.***

- *Which of these options does Rockwell prefer? Are there other ways by which the government should participate in Phase III?*

Rockwell believes that the best approach for government participation is as an equity partner since this will immediately reduce launch costs to all users at the start of RLV operations. With this approach, we can lower the initial private investor capital. This reduces the cost of money, which in turn, reduces the required cash flow to meet the necessary return on investment requirements.

A government equity co-investment reduces the amount of private equity investment, demonstrates the government commitment to this system (which is important as the US government is the largest single near-term customer), and allows a lower interest rate to be obtained for development financing. The combination of these factors allows the venture to offer a lower price to all users of the system, including the government, at the onset of operations.

In comparison, the second option requires a much higher price per launch to provide payback and it would be self defeating for it would not be as attractive to both government and commercial users.

From a commercial investment perspective, the earlier investments and demonstration of commitment by the largest single customer is a better answer. This will require earlier government funds in the RLV, but has a much greater impact in the venture financial viability and investment returns.

Other ways in which the government can participate include: RLV as a government-owned contractor-operated system, loan guarantees, limited partnership, service commitment, government-sponsored corporation, and market floor guarantor, to name a few. Rockwell is not advocating using any of these alternatives at this time.

7. *How fast do you - or your stockholders - expect to recoup your initial investment in the private RLV development?*

We believe we must offer our investors payback within about 10 years of beginning RLV operations. The actual timing of how quickly we recoup our initial investment in the RLV will be a function of the specific business arrangements assumed for the RLV business venture. We are continuing our business analyses and are looking at a variety of options to achieve this target payback period.

8. *Explain why it is in the long-term, strategic interest of your shareholders to invest in this new launch technology?*

It is in the long-term strategic interest of our shareholders to invest in this new launch technology for four fundamental reasons: 1) we want to replace our own product with the next generation system, 2) there is a large potential market opportunity with the RLV, 3) it will continue our strategic goal of commercializing our corporate business base, and 4) it allows us to extend our range of reusable space transportation products.

Rockwell has been involved with reusable space transportation over many years. Our work in this field has included the X15, the Space Shuttle, the X-34, and now the RLV. Past efforts have included major system developments as well as key technology areas. These include advanced composite structures, thermal protection systems, and reusable high-performance rocket engines. Investment in the RLV builds upon our corporate experience base and draws on past investments in key technologies for this business area.

Our assessment of the market potential for this area, if we can meet our demanding cost and operations goals, indicate a large potential commercial market. Investment in this new launch technology offers the potential of a significantly increased business activity for RLV and RLV-type systems, as well as synergy with other Rockwell business areas.

Rockwell International is a diversified high technology company. We make returns for our stockholders through investment and development of high technology areas to a variety of customers and markets. Over the past decade, Rockwell has gone from a company which was 70% dependent upon US government business to a company which now earns 70% of our revenues from commercial and international markets. Our focus is to diversify and develop new technology products for the markets. Investments in the RLV continue this strategic direction of commercializing core markets and technology, and will help transform a government-dominated market into a commercially-driven market.

Lastly, corporate investments in the RLV will extend our product line. Our current ventures include a small reusable launch system, the X-34 (a joint venture with Orbital Science Corporation) to serve small payloads. The RLV would extend our product line to cover larger payloads and additional sectors of the market.

9. *Congress can't force private industry to invest in the RLV development program. But Congress has other powers. Should Congress consider canceling its current contracts with existing launch systems, in order to give your companies the incentive to invest private capital in the RLV system?*

Rockwell believes it is premature for the government to consider canceling current contracts with existing launch systems as a way to provide incentive to invest private capital in the RLV systems. The objective of the program at this time is to determine the viability of RLV and provide the necessary data for a decision in 1999 whether or not to proceed with a commercially developed RLV. After that decision, it will take several years for the full scale operational RLV to be designed, produced and proven. To encourage private investment in a commercial RLV, the government needs a coherent policy of support and usage of commercial space transportation. It needs to recognize it is the largest single customer for domestic space transportation and commit its market demand to commercial space transportation. In addition, its role in future development and production of competing transportation systems should be clarified.

Additional Questions for Mr. Robert Minor from the November 1, 1995 Hearing Submitted by the Honorable Dana Rohrabacher

1. *Should the X-33 be developed and demonstrated under the currently planned Cooperative Agreement process, or through some other existing contract instrument?*

Yes, the X-33 should be developed and demonstrated under the currently planned Cooperative Agreement because it best lends itself to a low cost, commercial approach. For the flight test segment of the X-33 program, it may be expedient to conduct those tests under a different arrangement than the primary Cooperative Agreement because of third party indemnification issues.

The current Cooperative Agreements are very useful in fast track development programs because they greatly simplify government oversight, contractual reporting and payment milestones process for rapid development. They also place a significant burden upon industry for investment and liability.

The original charter for the Cooperative Agreement program was to a high level of non-government co-investment. But as the size of programs covered under the cooperative agreements have grown, this level of co-investment may be too high for industry to support as a co-investment based upon future business returns. A Cooperative Agreement can be used for the Phase II/ RLV program but the level of co-investment should be reduced, or made flexible, to allow industry to match their level and type of co-investment based on their specific program definition and the government's available funding profile.

Similarly, the Cooperative Agreements need clarification for indemnification and liability for the Phase II/X-33 program. The X-33 will be a hypersonic test vehicle, with the possibility of overflight of populated areas. Under X-vehicle programs, which are risky "push the envelope" development and test programs, the US government has typically accepted the liability for flight test programs. But there are no regulations in place to cover a Cooperative Agreement X-vehicle. This has been the cause of significant discussions in both the X-34 and X-33 programs and needs to be clarified for the Phase II/ X-33 Cooperative Agreements. An alternative would be to have the Cooperative Agreement produce and ground test the X-33 vehicle, with a contract and liability coverage from the US Government for the flight test program.

2. *Industry appears to want certain guarantees about either government funding or the level of government demand for launch services to the RLV operator(s). Is this true for your company, or do you simply want a guarantee that the government will purchase launch services through a free a competitive marketplace where the RLV operator can compete on price/performance?*

We recommend the government become an equity partner and provide a guaranteed market until the initial investment can be recovered because that approach will immediately lower the cost of services to the government as well as commercial users. We know the RLV will be more than competitive in costs and services in the out years -- but to obtain financing we must show how we can confidently repay our private investors and shareholders a competitive rate of return on their investment. This means we must charge a sufficiently high price in the short term, making it a challenge to overcome the investment hurdle with competitive prices. The US government, as the largest single user of space transportation, needs to provide some assurance that our offering of a competitive product on price and services will capture a sufficient share of their market. The price at which we can offer this service needs to be both cost-effective to the government and commercial users and sufficiently high enough to show a reasonable return to our investors.

3. *NASA's selection of the United Space Alliance to conduct shuttle operations affects all three X-33 teams. Could the loss of Shuttle business due to competition from RLV's influence your company's investment in the commercial RLV, assuming you won the X-33 project?*

Assuming we win the X-33 Phase II competition, Rockwell will aggressively pursue commercial RLV investment because of its large potential commercial growth market. This is a business issue. Our decision will be based on that expected business opportunity, not on the projected loss of Shuttle business.

At the same time, we are proud of the Shuttle and its accomplishments. We will continue to support its operations as long as there is a demand for its services. However, we recognize it will be replaced in the future because it has limited market growth potential. Based on our heritage and desire to remain the preeminent reusable space transportation system provider, Rockwell wants to be the company that builds and operates Shuttle's replacement.

McDonnell Douglas Aerospace
Response to
Questions from the Hon. F. James Sensenbrenner, Jr.

Q1. Explain what the cooperative Agreements require of industry, versus the performance expected from industry under a traditional program contract?

• From one point of view, the sole purpose of the X-33 program is to provide technology risk reduction to industry. To what extent does that overriding purpose conflict with the programmatic goal of fabricating the X-33 vehicle?

A1. **Cooperative agreements allow industry to determine the requirements for risk reduction necessary to enable commercial development of an RLV, which could serve both government and commercial missions. Traditional cost contracts provide a set of government requirements that the contractor must perform to for government-only missions, which can result in systems too costly for commercial competitiveness. Cooperative agreements allow industry to lead technology developments and require industry contributions; Traditional cost contracts don't.**

There is no conflict with the purpose of the X-33 program providing technology risk reduction to industry and the programmatic goal of fabricating the X-33 vehicle.

Q2. Is building the X-33 the best way to achieve the risk reduction purpose of this program?

• In terms of the program's areas of emphasis for reducing technology risk, which is considered the most important -- reducing the weight of the launcher, or increasing the power of the engine?

• In terms of reducing business risks, which is considered most important -- reducing manpower required to operate the vehicle, or increasing safety margins to prevent the loss of the vehicle?

A2. **If unlimited funding were available, the best way would be to develop a full-scale, orbital test vehicle to demonstrate the technology, operations, and cost. However, this option is not available. Therefore, with the options available, the X-33 program is the best way to achieve technical and cost risk reduction for the next generation reusable launch vehicle system. It allows a prudent validation of the single stage to orbit concept before**

proceeding into full scale development. The technology risk reduction achieved by flight testing a fully integrated X-33 vehicle in realistic flight environments is far greater than that which would be achieved by trying to simulate these environments in various ground tests of technology segments. In addition, the flight testing provides a demonstration of the total flight and ground operations, processing, timelines, manpower requirements, and costs, which would be lacking in a ground test only program. Additional ground tests can be used cost effectively to compliment the X-33 flight test program for further risk reduction in terms of scaleability, manufacturability, fatigue and life-cycle testing, and propulsion.

Reducing the weight of the vehicle to validate achievable mass fractions for SSTO is a major element of risk reduction. Equally important elements for risk reduction include demonstration of reusability and operability. Risk reduction for the engines is focused more on achieving higher levels of operability, than on "power."

In terms of business risks, reducing manpower requirements and providing adequate safety margins are both important. Operational costs are proportional to manpower requirements, and insurance costs are inversely proportional to safety/reliability (i.e., the lower the manpower requirements, the lower the operations costs; and the higher the reliability, the lower the insurance costs). These are both required to attract commercial customers. Both need to be driven to aircraft-like operations and reliability.

Q3. In January, NASA issued the Cooperative Agreement Notice to industry to which your company responded. At that time, NASA told you how much funding it would request from Congress through Phases 1 and 2 of the X-33 program.

- Why did your company enter into a Cooperative Agreement with the government, knowing of the funding profile, and yet cognizant it was not the correct funding profile?

- Did your company discuss changing the funding profile for the X-33 program with NASA prior to signing the Cooperative Agreements?

A3. **Our company has a successful history of performance on rapid prototyping programs of this nature. Our experience shows that maximum flexibility for program planning is provided with front loaded funding profiles. We discussed this with NASA during the Spring and Summer of 1995, prior to preliminary definition of our X-33, and gave them a ROM funding profile with suggested changes in FY'97.**

We entered into the X-33 Phase I Cooperative Agreement for the purpose of defining a prudent Phase II risk reduction program, generating preliminary business plans, and completing a preliminary design for the X-33. The funding profile for Phase I was and is appropriate for a study and definition contract. Near the end of the Phase I effort, we will define a balanced X-33 flight and ground test program for prudent risk reduction, and it will include the required cost profile. Our Phase II proposal will show how this cost profile meets the combined funding available from government and industry.

Q4. Is the total of NASA's X-33 funding -- about $1 billion through Fiscal Year 1999 -- enough to achieve the risk reduction goals of this program?

• If Congress agrees to move some of the funds forward from 1998 and 1999 to 1996 and 1997, is McDonnell Douglas willing to match government's increases in those years?

A4. **We believe the total of NASA's funding is sufficient to achieve the risk reduction goals of this program, as stated in the National Space Transportation Policy.**

The costs and contributions pertaining to our X-33 Phase II bid are competition sensitive at this time, but will be available after contract award.

Q5. Since industry has never raised private capital for the complete development of a new launch system, how is it that this program will stimulate such an enormous investment?

A5. **McDonnell Douglas is currently proceeding with the complete commercial development of a near-term launch system, called the Delta III. Other recent precedents, such as the privately financed multi-billion dollar Iridium satellite communications project, indicate the potential availability of private capital for new commercial space systems development and operation. The desire in both the government and industry for lower cost access to space appear sufficient to generate the required capital, provided acceptable business arrangements and risk reduction are achieved. Final system definition and business plans will be developed near the end of the Phase II program, based on X-33 results, for a decision on the next generation reusable launch vehicle.**

Q6. As you look ahead to Phase III, the government can work with you in at least two ways:

It can become your partner, and make an equity investment with your company in the development of the operational system. With that, of course, it would expect to enjoy a return on its investment, paid in the form of discounts on the launches it buys...

... Or it can stay out of your hair, be a good customer with its large demand for launch services, and pay its bills at market rates, on time.

• Which of these options does McDonnell Douglas prefer? Are there other ways by which the government should participate in Phase III?

A6. The government is a significant and required customer for commercial development of the RLV. Under the Phase I preliminary business planning effort, we are defining the nature of customer commitments and involvement required for Phase III go-ahead, just as we would for a new commercial aircraft development. The progress on this effort is still in work and is competition sensitive at this time. A set of preliminary recommendations will be included in our Phase II proposal and will be available after award.

Q7. How fast do you -- or your stockholder -- expect to recoup your initial investment in the private RLV development?

A7. These details are competition sensitive at this time. However, as an example, company/stockholders generally expect to recoup their investments in new commercial airliners in 4-7 years.

Q8. Explain why it is in the long-term, strategic interest of your shareholders to invest in this new launch technology?

A8. The technology for SSTO appears ready for demonstration. If successful, the technology can then be applied to significantly lower launch costs. The risk and cost are too great at this time for industry to proceed alone without government customers and/or involvement. It is in the best interest of the U.S. government to enable SSTO development in order to achieve significant savings to the taxpayer over the next several decades. It is in industry's interest to partner with the government on development of SSTO, to avert the risk of a foreign government SSTO development and domination of the global launch market.

Q9. Congress can't force private industry to invest in the RLV development program. But Congress has other powers. Should Congress consider canceling its current contracts with existing launch systems, in order to give your companies the incentive to invest private capital in the RLV system?

A9. **The current level of risk for SSTO is too high for the government to consider canceling contracts with existing launch systems. We agree with the National Space Transportation Policy objectives of demonstrating the technology, including X-33, for a government and industry decision by the end of the decade on whether to proceed with a next generation reusable launch system.**

McDonnell Douglas Aerospace
Response to
Questions from the Hon. Dana Rohrabacher

Q1. Should the X-33 be developed and demonstrated under the currently planned Cooperative Agreement process, or through some other existing contract instrument?

A1. **The Phase II X-33 program can be developed and demonstrated under the planned Cooperative Agreement process. It is similar to that being done on the DC-XA, but on a much larger scale. A traditional cost contract also has advantages.**

Q2. Industry appears to want certain guarantees about either government funding or the level of government demand for launch services to the RLV operator (s). Is this true for your company, or do you simply want a guarantee that the government will purchase launch services through a free and competitive marketplace where the RLV operator can compete on price/performance?

A2. **In 1999 if a decision is made by industry to proceed with commercial development of the RLV, industry at that time would expect to have a sufficient number of firm orders providing an acceptable financial risk. The same is true at the time of authority to proceed with commercial airliner development. The size of the commercial space launch market, without government payloads, projected during the years for RLV initial operations is insufficient to achieve payback on the investment required. Therefore, the government is a significant and required customer for commercial development of the RLV. Under our X-33 Phase I effort, we are defining the nature of customer commitments and involvement required for Phase III go-ahead. The progress on this effort is still in work and is competition sensitive at this time. A set of preliminary recommendations will be included in our X-33 Phase II proposal and will be available after award.**

Q3. Both members of your team are interested in commercially operating the space station? Will your companies commit to allowing a competitive market in space station-oriented transportation if you win a commercial station operations contract?

A3. **Yes, but only under the rules of fair competition. If the launches are offered by countries as an in-kind contribution to the program, a private investor cannot compete. Also, if the non-market economies are not yet established as a true market, there is no way to have a free and fair competition for launch services.**

Lockheed Martin Skunk Works
1011 Lockheed Way Palmdale, CA 93599

LOCKHEED MARTIN

December 20, 1995

Honorable F. James Sensenbrenner
Honorable Dana Rohrabacher
Subcommittee on Space and Aeronautics
Committee on Science
2230 Rayburn House Office Building
Washington, D.C. 20515

Regarding: Follow-up questions for Mr. Jack Gordon concerning his testimony on "X-33 Reusable Launch Vehicle: A New Way of Doing Business?" given November 1, 1995

Gentlemen:

I appreciate this opportunity to clarify the Lockheed Martin position in the areas identified in your request.

The X-33 Program presents both government and industry with significant challenges in technical as well as business areas. It is vital that government, industry and Wall Street work together to resolve these challenges. I look forward to continuing our dialog on this topic and still believe that the establishment of a special board to develop a workable financing solution is crucial to making the reusable launch vehicle and affordable access to space a reality.

I have reviewed the transcripts from the hearing and have no corrections to recommend. I trust that the following responses adequately answer your questions. I am available at your convenience for further clarification as required.

Questions submitted by the Honorable F. James Sensenbrenner, Jr.

1. ***Explain what the Cooperative Agreements require of industry, versus the performance expected from industry under a traditional program contract?***

From one point of view, the sole purpose of the X-33 program is to provide technology risk reduction to industry. To what extent does that overriding purpose conflict with the programmatic goal of fabricating the X-33 vehicle?

In general, Cooperative Agreements reflect a partnership orientation toward resources and products versus the traditional contracting concept whereby the government pays and industry produces. Cooperative Agreements require the government to be substantially involved and to have a meaningful role, not just an oversight role, in establishing and accomplishing the tasks

under the agreement. A Cooperative Agreement eases the investment approach whereby industry is able to use IRAD/B&P in support of the Cooperative Agreement. A traditional contract requires more direct cost sharing. Either party can revoke a Cooperative Agreement in whole or in part after discussions between the parties.

Presently, our primary concerns with the Cooperative Agreement for X-33 are indemnification and liability issues. Our recent experience on Cooperative Agreement NCC8-76, the Aerospike Engine Demonstration, indicates that the Cooperative Agreement does not adequately address liability coverage for industry. Traditional contracts provide coverage in these areas. This is a significant issue for industry.

In addition, the committee raised an issue regarding X-33 vehicle and RLV risk reduction. The additional funding being requested by NASA to cover large scale ground testing and 2 vehicles further reduces the risk for RLV technologies. While we believe that large scale ground testing may be more transferable for RLV development, the role of the X-33 vehicle is to provide technology demonstration in an operational environment. It is our belief that the additional funding will assist the government in achieving the objective of reducing risk. Government/industry and Wall Street will need to work together and resolve the degree of risk reduction necessary for the investment community.

2. ***Is building the X-33 the best way to achieve the risk reduction purpose of this program?***

In terms of the program's areas of emphasis for reducing technology risk, which is considered the most important -- reducing the weight of the launcher, or increasing the power of the engine?

In terms of reducing business risks, which is considered most important -- reducing manpower required to operate the vehicle, or increasing safety margins to prevent the loss of the vehicle?

As addressed in your question, the X-33 is a major element in the Lockheed Martin technical risk reduction program. Our unique approach focuses on developing a totally integrated system. Consequently, trades between installed propulsion thrust, structure weight and materials must be properly balanced within the total system. Therefore, it is not appropriate to place greater importance on one element over another.

Quantum improvements in launch operations and vehicle and system reliability are both key elements of a successful business strategy. Our design premises an aircraft-like system, in which reliability/maintainability requirements are primary considerations during development in order to ensure high safety margins while greatly reducing operational manpower. Our approach focuses on minimizing the chance of loss of a vehicle.

3. ***In January, NASA issued the Cooperative Agreement Notice to industry to which your company responded. At that time, NASA told you how much funding it would request from Congress through Phases 1 and 2 of the X-33 Program.***

Why did your company enter into a Cooperative Agreement with the government, knowing of the funding profile, and yet cognizant it was not the correct funding profile?

Did your company discuss changing the funding profile for the X-33 program with NASA prior to signing the Cooperative Agreements?

We entered into the X-33 Phase I Cooperative Agreement because we endorse NASA's objective of achieving single stage to orbit. In fact, at the time of the CAN release, Lockheed Martin was considering a full complement of options including a full scale development program after Phase I. We were assuming that the issues of funding and launch commitments would have been defined at that time. A requirement of Phase I is the development of a Phase II program including defining necessary resources. With respect to the Lockheed position on the CAN, there are a number of items to be defined in Phase I including several being considered by this committee: funding, launch commitments, financing, etc. These are all things that the government/industry team are in the process of developing. Given the significance of these issues, we must continually reassess the overall program viability and feasibility.

4. ***Is the total of NASA's X-33 funding -- about $1 billion through Fiscal Year 1999 -- enough to achieve the risk reduction goals of this program?***

If Congress agrees to move some of the funds forward from 1998 and 1999 to 1996 and 1997, is Lockheed Martin willing to match government's increase in those years?

The X-33 funding is a critical issue. Your question approximates $1 billion to support the Phase II program. It is our understanding that current funds are $941 million less approximately $100 million to support government program office efforts. Consequently, the $1 billion is really closer to $800 million.

We believe even this level of funding can support the risk reduction goals of the X-33 Program. We are establishing a plan to fit within this level of funds augmented with appropriate discretionary funding from our company. NASA has initiated discussions regarding additional funding needs for large scale ground testing and a partial second vehicle. The summary of industry and NASA inputs led to the proposed $580 million for additional risk reduction. As I indicated in my earlier statement, this additional funding, in concert with the basic X-33 funding, will enhance key technology risk reduction. These additional funds would go much further towards ensuring a financially viable Phase III by reducing RLV development costs and producing a perception of lower risk for potential investors.

With respect to the funding shift we are not aware of the specific amounts being considered. We do believe that the initial funding in the first two years appeared to be low. By shifting funds forward a funding profile better matched to the real spending would result. However, it is important to recognize that shifting money, while reducing programmatic risk, does not increase the risk reduction effort. The only way to increase risk reduction would be with

additional total funding. Corporate provided resources are driven by the perceived investment opportunity that will provide an appropriate return for our shareholders.

5. ***Since industry has never raised private capital for the complete development of a new launch system, how is it that this program will stimulate such an enormous investment?***

The X-33 program, as structured, reduces the technical risk of achieving single-stage-to-orbit. Phase II must define an assured market, backed by government commitments, to generate acceptable financial returns in a reasonable period of time if private funding is to be achieved. Current market conditions and recent discussions with Wall Street make it very difficult to forecast the behavior of the financial market in the RLV timeframe. For this reason, the special board we have proposed should be implemented to establish the feasibility of private financing assuming the launch commitment issued is resolved.

6. ***As you look ahead to Phase III, the government can work with you in at least two ways:***

   It can become your partner, and make an equity investment with your company in the development of the operational system. With that, of course, it would expect to enjoy a return on its investment, paid in the form of discounts on the launches it buys...

   ...Or it can stay out of your hair, be a good customer with its large demand for launch services, and pay its bills at market rates, on time.

Which of these options does Lockheed Martin prefer? Are there other ways by which the government should participate in Phase III?

At this point in time, the two choices provided in your question may not be mutually exclusive. In order for this to work, the government, a major partner and customer, must avoid becoming too involved in the day to day development activities of the RLV. In our analysis to date, we have anticipated that the government would be a secured business partner over the first five years of launch services and essentially provide $2.5 billion of funding annually to replace projected Space Shuttle missions. This overall value is equivalent to or less than projected shuttle funding requirements. The $2.5 billion represents launch services with an anticipated rate of 15 launches a year. After this five year period, the services would be based upon market prices.

7. ***How fast do you -- or your stockholders -- expect to recoup your initial investment in the private RLV development?***

Timely return on the RLV investment is crucial to generating acceptable financial returns. The specifics are a function of the nature of the government launch commitments. In our preliminary planning we have considered a range of 10 years for investment recoupment with a reasonable return from the beginning of RLV development (Phase III).

8. ***Explain why it is in the long-term, strategic interest of your shareholders to invest in this new launch technology?***

There are two primary reasons that relate the RLV program to the strategic interests of the Lockheed Martin shareholders. Space launch and operations is a core business for Lockheed Martin. The second reason, and most critical, is the economic return that the RLV service can offer. It is very important that the United States regain its launch leadership that the RLV affords.

9. ***Congress can't force private industry to invest in the RLV development program. But Congress has other powers. Should Congress consider canceling its current contracts with existing launch systems, in order to give your companies the incentive to invest private capital in the RLV system?***

Congress has a very important role in the development of the overall RLV concept. Congress has funded NASA to develop a plan to achieve RLV development without severely impacting ongoing operations in the near term. This phased approach represents a viable solution to achieving the U.S. Government's affordable access to space objective. Cancellation of existing launch system contracts would result in increased government liability with no clear cut benefit. A wiser course may be to develop a plan which would not program future spending in shuttle modernization and to utilize savings from shuttle privatization for RLV development.

In addition, Congress should host the special economic SSTO board that we have recommended. Only with Congress' joint ownership of the business risk issues can a suitable resolution be achieved that will satisfy privately funded development within acceptable government guidelines.

Questions submitted by the Honorable Dana Rohrabacher

1. ***Should the X-33 be developed and demonstrated under the currently planned Cooperative Agreement process, or through some other existing contract instrument?***

Our preference would be a Cooperative Agreement with the necessary funding, liability, and indemnification coverage. In addition, please refer to answer No. 1 under questions submitted by the Honorable F. James Sensenbrenner.

2. ***Industry appears to want certain guarantees about either government funding or the level of government demand for launch services to the RLV operator(s). Is this true for your company, or do you simply want a guarantee that the government will purchase launch services through a free and competitive marketplace where the RLV operator can compete on price/performance?***

It must be recognized that the investment is for the launch services and not just for the vehicle development and manufacture. Our assumptions have included a stable source of government funding for the first five years of operation at a level below anticipated shuttle costs in order to attract private financing. Subsequently, launch services would be based on a competitive market. This two phased approach is essential to generating an acceptable rate of return.

3. ***NASA's selection of the United Space Alliance to conduct shuttle operations affects all three X-33 teams. Could the loss of Shuttle business due to competition from RLVs influence your company's investment in the commercial RLV, assuming you won the X-33 project?***

We do not believe that the loss of the Shuttle business will influence the company's investment in RLV. The transition between STS and RLV will be complex. The government, as a major customer of both systems, will have insight and influence on the timing of this transition.

I appreciate the opportunity to respond to your questions. In addition, I hope that my answers have highlighted areas of concern to us. These include indemnification liability coverage for industry within the Cooperative Agreement framework, government launch commitments in Phase III, and the creation of a special board comprised of government, industry and Wall Street to work these issues. Until such time that the specifics of the these issues are resolved, it will be difficult to develop any detailed Phase III investment plan.

Should you have any questions, please feel free to contact my office.

Jack S. Gordon

Jack S. Gordon
President
Lockheed Martin Skunk Works

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RESPONSES TO MEMBER QUESTIONS FROM DR. RAY WILLIAMSON

Additional Questions -- Dana Rohrabacher

1. Should the X-33 be developed and demonstrated under the currently planned Cooperative Agreement process, or through some other existing contract instrument?

The Cooperative Agreement currently in use seems appropriate for developing the X-33. It involves both NASA and industry in the development process of a highly experimental launch vehicle, requiring each to commit resources to the effort.

2. Industry appears to want certain guarantees about either government funding or the level of government demand for launch services to the RLV operator(s). Do you believe this is an accurate assumption for the X-33 industry teams? Do you believe this is an accurate assumption for the X-33 industry teams? Do you believe that the teams could simply rely on a guarantee that the government will purchase launch services through a free and competitive marketplace where the RLV operator can compete on price/performance?

For industry to commit substantial funds to the development of an RLV, it will indeed need some sort of assurances that a market for launch services will exist. As I have testified, the existing commercial market is much too small and competition from expendable launch vehicles too great for an RLV corporation to depend solely or even mainly on the commercial market for launch services. Lower transportation costs will benefit the government as well as industry. Hence, because government payloads constitute a large segment of the total available launch services market, some sort of government assistance would be appropriate. Although prior to the development of the X-33, it is impossible to predict the development cost of an operational RLV with any degree of certainty, I suspect that the level of technical and financial risk for RLV development will be much too high to count on private development in the absence of substantial government funding or firm guarantees. It is otherwise too easy for government agencies and Congress to change their minds about purchases of launch services.

3. Costs are a function of both technology and market environment. What market policy (as opposed to technology funding) initiatives can the Congress take to encourage the greatest possible sustained reduction in space transportation costs?

Probably the best way to assure interest in RLV development from private companies is to find ways to assure a government market that the companies can depend upon, assuming they meet their cost (and price) reduction goals. This could mean, for example, specifying in law a guaranteed average minimum number of government payloads of a specified size range per year and being prepared to pay for them even if the average payload demand over a few years declines.

Additional Questions -- Ralph M. Hall:

1. How many Reusable Launch Vehicles would be required to meet the likely annual government and commercial demand for launch services in the period 2005-2015? What RLV flight rate does that estimate assume?

Estimates for the flight rate in the period 2005-2015 are highly uncertain. The market available to U.S. launch services companies consists of Department of Defense payloads, NASA and NOAA payloads, and U.S. and foreign commercial payloads. Estimates of demand for medium to large payloads during the period in question range from 25 to 45, depending on: continued growth in the communications satellite industry, continued government funding for defense and non-defense space activity. If an RLV could capture most of these payloads, it might prove profitable. However, as I have testified, investors in RLV development must take into account the effects of competition from the ELV industry in the U.S. and abroad, as well as the demand for launch services. New markets for space transportation may be necessary to give investors the necessary confidence that RLV investments would pay off before 2010 or so.

2. What would be required for an RLV to be able to provide launch services to geostationary orbits?

Using an RLV to place satellites in geostationary orbits will require an upper stage to place the satellites in geostationary transfer orbit (GTO). ELVs, by contrast, can place satellites directly in GTO. They therefore have a technical advantage that translates to a slight cost advantage compared to RLVs. If, however, an RLV meets the goal of vastly reduced price, it would easily overcome such a cost advantage.

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